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AUTHOR White, Geoffrey
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ABSTRACT

An introduction to the subject of federal support to academic research is presented. It is noted that total federal support to academic research in fiscal 1976 came to roughly $4.5 billion, close to a third of all federal dollars spent on higher education. Top universities receive 25 percent or more of their operating budgets from federal research support, most spent on basic research rather than applied research or development. This kind of research has special characteristics that affect the way it is funded: (1) since results are unpredictable, the researcher needs great flexibility; (2) broad dissemination of results is critical; and (3) the best research is much more important than second-best, and requires special attention. There are many reasons the federal government should assume responsibility for basic research. Many controversial issues surrounding funding have to do with funds administration. These include peer review, the regulation of the substance of research, cost sharing by the institution, allocation among disciplines breadth of support among institutions rather than restriction to a few large universities, lack of centralized support planning at the federal level, and mechanisms of making awards, such as step funding, project grants, institutional grants, research center grants, basic contracts, regranting, and discretionary funds. It is suggested that there is a critical level of funding below which the health of the entire scientific enterprise suffers. In some fields it is felt that funding is now below that level. However, the basic design of the system that supports academic research may need more attention than simple funding levels. Some data charts are included. (MSE)

Sloan Commission on Government
and Higher Education

Working Paper

Preliminary Draft

FEDERAL SUPPORT OF ACADEMIC RESEARCH

by

Geoffrey White

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I. INTRODUCTION

This paper is intended to serve as an introduction to the subject of federal support to academic research. Federal sponsorship of academic research is a fairly recent development; for all practical purposes, it began with the weapons projects of the Office of Scientific Research and Development during World War II. Since then, however, the dollar volume of federal sponsorship has grown tremendously, enabling two or three dozen American universities to join the ranks of the world's foremost performers of first-rate science. Federal research dollars have transformed the top American universities from primarily educational institutions into centers of scientific discovery operating on a scale and at a level of excellence that was not imagined forty years ago. If the federal dollars were taken away, they could not hope to maintain their research activities at the levels to which they have become accustomed over the past forty years.

In fiscal year 1976 (the most recent year for which reliable figures are available), the federal government obligated $2.4 billion for research performed at universities and colleges. Another $0.6 billion was obligated for other on-campus scientific activities, such as laboratory construction and research fellowships, while $1.5 billion was budgeted for twenty-one major research centers administered separately by universities, known as Federally Funded Research and Development Centers, or FFRDCs. Thus total federal support to academic research in fiscal 1976 came to roughly $4.5

billion, or close to a third of all federal dollars spent on higher education.

Federal sponsorship of academic research, concentrated as it is among a few institutions (thirty institutions receive half of the funds), has had an even greater effect on academic science than these aggregate numbers suggest. While the great majority of colleges and universities have been relatively unaffected by federal research funding, the top universities, at which most first-rate scientific research takes place, now typically receive twenty-five percent or more of their total operating budgets from federal research grants and contracts. (Fully seventy percent of the budget of the Massachusetts Institute of Technology, including Lincoln Laboratory, an FFRDC, comes from federally-sponsored research.) For these institutions, every aspect of federally-sponsored research policy has acquired great importance.

Federal funding of academic research is not simply a matter of higher education policy. Basic scientific research is an essential part of postgraduate education, and this explains why universities are the primary, and in many fields the exclusive locus of basic research in the United States. But basic research is also a national resource in its own right. The federal programs which award research grants and contracts to academic researchers were created not to promote higher education, but to advance scientific understanding. This paper will attempt to describe how these programs evolved; to tell something of how they work and what they are meant to achieve; and most importantly, to discuss the problems

that are now being experienced in federal/academic research relationships, and how changes in various federal policies affect academic investigators, research universities, and the general health of basic science in this country.

Section II will discuss the special nature of basic research -- what purposes it serves and under what conditions it can be performed -- and the role of academic research. Section III of this paper will discuss eight specific issues of federal research policy that seem particularly important today. Appendix A will give a brief history of federal support to academic research and a snapshot of current federal support; how much is spent, by whom, and for what. Appendix B will describe in some detail the principal mode of federal support -- the project grant.

The reader will find that this paper takes a point of view that is sympathetic to academic research. The author is persuaded that basic research produces great benefits to society; that the conduct of basic research must be left largely in the hands of scientists; and that the federal government should make a substantial investment in academic science. There is a substantial body of evidence, based largely on our past experience with scientific research, that suggests that these statements are true. Nevertheless, one cannot prove or disprove them, but only accept or reject them, largely as an article of faith. This paper might have taken a less conservative and more neutral viewpoint, putting forth arguments for spending less money on academic research, as well as for spending more. For better or for worse, it attempts instead to convince the reader of the special nature of scientific research, while

still trying not to end up as a special pleading for the interests of the academic research community.

II. THE NATURE OF BASIC RESEARCH

The federal government now spends about $4.5 billion annually on academic science, broadly defined. Some of this money supports projects which are aimed at using scientific knowledge to meet specific federal and public needs, but most of the money supports work which is aimed at advancing the state of scientific knowledge itself. The distinction is an important one, but one which is often ignored or poorly understood. A brief examination of the special nature of basic research will do much to clarify the discussion in the following sections.

Basic or fundamental research is undertaken to advance scientific understanding. In contrast, applied research is directed at the practical applications of scientific knowledge, while development involves the actual execution of such applications. For example, an investigator seeking to understand the structure of the atom is engaged in basic research. A second investigator, who uses this understanding to derive the principles of operation of an atomic pile that could be used as a source of commercial power, is engaged in applied research. A third investigator, who uses the work of the first two to design and construct a working pile, is engaged in development.

The boundary between basic and applied research is a fuzzy one. A scientist engaged in the most basic research may still be aware of the practical applications of his work, and one engaged in applied research may contribute to abstract scientific understanding. Nevertheless, there is a distinction between research

in which the line of inquiry is dictated by the search for abstract knowledge, and research in which it is dictated by the search for useful applications. A microbiologist engaged in basic research is guided by the intrinsic logic of microbiology, rather than by any extrinsic considerations. He will decide what research topics to pursue, which particular experiments to conduct, and what methods to use on the basis of what is more likely to extend his understanding of microbiology, rather than on the basis of what is likely to lead to a cure for a certain disease.

Since basic research attempts to extend the bounds of knowledge, its results cannot be known in advance; indeed, it has been said that if the results of an experiement can be predicted in advance, the experiment is not worth doing. Sometimes the full scientific significance of an investigation is not understood until years after the fact. This characteristic of basic research has two important consequences for the way in which it is organized.

First, if the researcher cannot predict what the results of an experiment will be, or even which experiments will produce significant results, then it is essential that he be allowed flexibility in choosing the course, methods, and goals of research. This is in contrast to an investigator undertaking a development project, where the objective is known in advance and the scientific basis for achieving it is fairly well understood. The latter investigator can reasonably be required to formulate a research plan in advance and adhere to it, but the basic researcher must be free to select appropriate experimental procedures and, if

necessary, to change them in mid-course to take advantage of what is learned in the course of research.

Second, basic research depends critically on the broad dissemination of the results of research. The results of one investigator's research frequently provide the key to another's investigation, often in ways that are unforeseen. Furthermore, researchers refine their understanding of their own research through interaction with other scientists working on related topics. It is important that this interaction be widely based, since the researchers at two distant universities, or in two different countries, are often working on complementary approaches to the same set of problems and, therefore, may benefit greatly from the opportunity to discuss their work together. All this is as true for theoreticians as it is for experimentalists. With very rare exceptions, scientists cannot work in a vacuum; scientists depend on other scientists for intellectual stimulation. Therefore, it is important that the results of research be disseminated as promptly and as widely as possible, and that researchers frequently be afforded the opportunity to discuss work in their field with their colleagues from other centers of research.

Another characteristic of basic scientific research is that the best is much more important than the second-best. The best research pushes forward the frontiers of scientific understanding, yielding new knowledge that both provides the foundation for further advances, and in some cases also leads to technological developments of economic value to society. Therefore, it is important that research funds be administered in such a way that the best research receives support.

Since there is no reliable way to predict the results of research in advance, how is the best research to be singled out for support? The best, and perhaps the only way to identify first-rate research is to rely on the judgment of scientists who are familiar with the field of research as to the scientific merits of a particular research proposal and the track record of the researcher in performing first-rate science. This is often referred to as the merit system, and it is based on the belief that leading research scientists are themselves the best, and perhaps the only competent judges of what research is first-rate and what is second-rate.

A related issue is the notion of "critical mass" in the funding of research. First-rate research cannot be conducted on an arbitrarily small budget; some minimum amount of funds is required to produce useful results.

This is clearly true for "big science," such as high energy physics, astronomy, and oceanographic research, which requires large and expensive facilities if any research is to be performed. In high energy physics, for example, a few million dollars is not much better than nothing; there must be enough funds to operate an accelerator if any research is to take place. And, more subtly, since the state-of-the-art in high energy physics is constantly advancing, the possibility of really significant advances depends on enough funding to build accelerators more powerful than those already in place.

The same logic applies to "little science:" research which does not require massive facilities. In any field, there must be

enough money to support a fairly large community of researchers if the field is to advance, and to attract graduate students. The high cost of instrumentation also contributes to the notion of critical mass in "little science." In recent years, research in chemistry and biology has become increasingly dependent on the use of spectrometers, electron microscopes, ultracentrifuges, electronic computers, and other instruments costing tens or hundreds of thousands of dollars. Researchers with only modest instrumentation budgets will still be able to perform research, but they will find they are unable to undertake the most interesting and productive experiments.

"Critical mass" is relevant to the funding of an individual project, of a research center, of an entire discipline, and even of the aggregate national research effort. A certain minimum commitment of federal funds is necessary to support the capability to perform basic research in the United States. How much more than that minimum is provided will determine how vigorous the scientific enterprise will be and how rapidly it will advance. It has been suggested that the health of basic science requires periodic major breakthroughs which shake up researchers who have grown attached to standard theories, and bring forward younger researchers who advance radical new theories. According to this view, the federal government should, for the health of the scientific enterprise, support enough research to produce perhaps one such breakthrough every five or ten years in each discipline receiving support. Otherwise, these disciplines will grow stale, and the United States will lose its position of world leadership in science. Such a loss would be

damaging not only to American scientific progress, but also to graduate education and to the interplay between science and technology, as we will see below.

Before going any further, we should ask why the government should support basic research. First, what benefits are produced by basic research? And second, why is it necessary for the federal government to assume the responsibility for providing these benefits?

Basic Research and Technological Innovation: First, fundamental scientific knowledge leads to technological advances that augment our military capability, our health, and our productive capacity. There are many examples to back up this position, including some spectacular success stories. The atomic bomb and atomic energy were clearly made possible by basic research on atomic structure; development of the transistor, and the microelectronics revolution were made possible by basic research in solid state physics, and so on. But there is also much basic research which has not yet produced substantial economic benefits, and which is not likely to in the foreseeable future.

Efforts have been made to assess the link between basic science and technology by identifying the technological by-products of particular breakthroughs in basic science, and by tracing the scientific roots of particular technological advances. One such study, the 1968 Technology in Retrospect and Critical Events in Science Study (TRACES), attempted to identify the events which led to five technological innovations, including the oral contraceptive pill, the electron microscope, and the videotape recorder.

TRACES found that over seventy percent of the events leading to these innovations had their roots in basic research, and that the largest number of these basic research "events" occurred between twenty and thirty years prior to the corresponding innovation.

A second study, undertaken in 1964, was the Defense Department's Project Hindsight, which examined twenty weapons systems and tried to isolate scientific and technological events which contributed to their development. Of the 710 events that were identified, fewer than ten percent were classified as scientific events, and fewer than one percent involved undirected basic research.

There is a constant interplay between scientific discovery and technological advance, but as these two studies show, the relationship between the two is difficult to pin down. The time lag between scientific discovery and ultimate application is often great, and while economic benefits can often be shown, after the fact, to have resulted from basic research, it is extremely difficult to predict beforehand which research projects will lead to practical applications, what the applications will be, or how soon they will materialize.

We conclude that some basic research projects will lead fairly soon to useful applications, while others will do so later or not at all; that some of the projects which "pay off" will do so in completely unexpected ways; that the value of basic research which does pay off is, on average, very large; but that it is impossible to single out in advance those projects that will yield applications. This view leads to the conclusion that support should

be given to a broad spectrum of basic research projects, without undue attention to their applicability to social needs.

Basic Research as a Technological Resource: Experience shows that a strong effort in basic research increases our capacity to do applied research and development. Applied scientists and engineers are more productive when they are in close contact with scientists engaged in basic research in the disciplines that underlie their work. This is true both in general, and at the level of an individual laboratory or research center.

Furthermore, basic research creates a reserve of scientific expertise which can be mobilized for an applied research effort in time of national need.

Basic Research and Graduate Education: Basic research is a necessary ingredient in graduate education. The central goal of doctoral training in the natural sciences (and, for that matter, in the social sciences and humanities) is to train the student to work at the forefront of his or her discipline. An essential ingredient in such training is some form of apprenticeship to active researchers. Unless there is a locus for research at the university, or nearby, universities will find it difficult to attract the best scientists to their faculties, and to educate true scholars.

The Intrinsic Value of Basic Research: Finally, basic research provides benefits that transcend its purely economic value. The desire to understand the workings of nature is one of man's most fundamental traits. This, more than material gains produced by science, explains why humanity has, since antiquity, pursued scientific knowledge, and

why it has taken so much pride in its scientific and technological achievements.

While science and technology do not have as broad an appeal as some other forms of human endeavor, such as music, their appeal is by no means limited to those actually engaged in research. On some occasions, such as our landing a man on the moon, they have generated enormous national interest and pride. The purely aesthetic appreciation of science, while not likely to weigh heavily in R & D policy-making, should be counted as a definite benefit of basic scientific research.

The Rationale of Public Support

Many economic activities produce benefits to society, yet do not receive federal support. The justification for federal support of basic research lies in the fact that, for a variety of reasons, the private marketplace cannot be relied on to produce enough basic research.

The market will generally pay for research only when the results of research are of direct value to business firms. Therefore, research topics of primarily military interest will be paid for by the federal government or not at all. And in any field in which the federal government is a major producer, it must assume the role of funder of related research as well.

Even when basic research is of direct value to industry, the market will tend to underinvest in it for a variety of reasons: because of the high capital cost of research, because of the uncertain return to research, because of the long delay between investment and payoff, and because of the difficulty in appropriating the fruits of a particular research finding to any one firm.

For these reasons, the private marketplace will consistently underinvest in basic research, and the public will benefit from federal spending on basic research to supplement private spending.

In fiscal year 1975, the federal government spent approximately $3 billion on basic research. Twenty-one percent of the total was spent intramurally, in federal laboratories. Another thirteen percent was spent on basic research conducted by industry and by non-profit institutions other than universities and colleges. By far the biggest performer of federally-sponsored basic research was the nation's universities and colleges, which received fifty-six percent of the total. If the twenty-one Federally Funded Research and Development Centers administered by universities and colleges are included, the academic share of federal basic research funding is two-thirds of the total.

TABLE 1

Federal Basic Research Expenditures, by Performer

FY 1975	(Dollars in Millions)
Industry	154
Federal Government	645
Universities and Colleges	1,691
University-administered FFRDCs	307
Other Non-profit Institutions	245

The FFRDCs are, of course, entirely funded by the federal government; basic research at universities and colleges is nearly so. In FY 1975, seventy-one percent of all basic research performed at universities and colleges was funded by the federal government. Another twenty percent was funded from the academic institutions' own funds while industry and other non-profit institutions provided only ten percent of the funds.

TABLE 2

Academic Basic Research Expenditures, by Source

FY 1975 (Dollars in Millions)

	Universities and Colleges	FFRDCs
Industry	71	--
Federal Government	1,691	307
Universities & Colleges	470	--
Other Non-profit Institutions	162	--

(The figure for the contribution of universities and colleges includes state and local government funds and, therefore, conceals a considerable state contribution to basic research at public universities and colleges, included as a line item in the annual general fund appropriation. Moreover, much of the states' contribution to research at public universities does not show up at all here. Line item support for various overhead expenses implicitly includes a contribution to the indirect costs of research, both sponsored and

unsponsored. Furthermore, the general fund appropriation often includes a capitation formula of so many dollars per full-time equivalent enrolled student. The figure is usually much higher for graduate students than for undergraduates, thus providing support for the research activities associated with Ph.D. programs.)

Why is so much of the nation's basic research performed at academic institutions? Part of the answer is historical; Appendix A of this paper will trace the federal/academic partnership for the performance of research that began with World War II research projects funded by OSRD. But most of the answer lies in the way that graduate education and basic research complement each other. A previous section stated that research is a necessary ingredient in graduate education. Many scientists believe that the presence of graduate students and post-doctoral fellows is just as essential to the conduct of research. By questioning the accepted theories, and by readily adopting and defending new theories, they act as a spur to established researchers, preventing them from becoming complacent. By bringing new blood into their field, they prevent their field from going stale.

Furthermore, the university provides a broad base for research and scholarship which enriches the scientific research that is performed there. By stressing the importance of scholarship and understanding for their own sake, the university creates an atmosphere supportive of basic research which is difficult to duplicate in an industrial or government laboratory. And by assembling a common community of scholars working in many varied disciplines, the university promotes an interdisciplinary exchange of ideas which is equally difficult to duplicate elsewhere.19

Universities and colleges perform a significant amount of applied research: $851 million in FY 1975, of which $516 million was sponsored by the federal government. They also perform a small amount of development: $148 million in FY 1975, of which $78 million was federally sponsored. But applied academic research is a small part, and academic development an insignificant part of the national totals.

The $987 million spent by university-administered FFRDCs was almost evenly divided among basic research, applied research, and development. This reflects the wide variation in the kind of work performed at FFRDCs. Some, like the Stanford Linear Accelerator, are involved almost exclusively with basic research, and are closely tied to universities, with considerable traffic in researchers and graduate students between Center and university departments. Others, like Lincoln Laboratory at MIT, perform applied research and development work, and have little in common with the universities that administer them. (A list of FFRDCs is given at the end of this paper.)

Because of this variation, it is difficult to decide whether or not to include the FFRDCs when estimating the amount of federal support to academic research. The analyst who would make such estimates must also decide whether to include applied research and development conducted at universities along with basic research, and whether to include funds for research plant, fellowships, and other scientific activities along with funds for the actual conduct of research. Throughout this paper, when dollar figures are given for academic research and no specific mention is made of FFRDCs,

the figures include only research performed within the university proper. The figures will also include only funds for the conduct of research, and not for other scientific activities, unless noted otherwise. However, the figures will include the relatively small amounts of applied research and development along with the basic research performed on campus. Thus, when figures are cited for federal support to academic research, they will correspond to the $2.4 billion figure given on page 1 of this paper, and "academic research" will be synonymous with on-campus academic R & D. This choice is dictated in part by the availability of reliable data on federal support to academic science, but it also reflects the author's belief that the most important policy issues arise in the context of federally-sponsored on-campus projects.

III. SOME MAJOR ISSUES OF FEDERAL RESEARCH POLICY

A great deal of attention has been focused in recent years on the amount of federal money being spent on academic research, on the federal regulations that govern the use of these funds, and on some broad questions of how the federal government should allocate these funds. Which of these issues is most pressing depends in large part on who the judge is. To the investigator who performs the research, the level of funding is by far the most important, for it determines, more than anything else, how much research can be undertaken and how rapidly scientific understanding will advance -- in short, just how large and fruitful the scientific enterprise will be. In more practical terms, the level of funding will determine how easily an individual investigator will acquire support for his research project, how many faculty positions will be open to him, and how rapidly he will be able to advance.

Federal regulations governing the use of funds are less important to the investigator, but are of paramount importance to the educational institution. Regulations can increase the institution's administrative and paperwork costs, necessitate expensive compliance efforts, and reduce the amount of federal dollars that the institution itself receives.

Then there are the broad issues of the design of federal research programs: how competing projects should be evaluated, whether federal programs should be centralized or decentralized, how much emphasis should be placed on directing research toward

national needs, and so on. These may be of great interest to a policymaker who seeks to improve the performance of federal research programs, but they are not of such pressing importance to university investigators and administrators.

We do not wish to press these distinctions too far. For example, an investigator will be greatly interested in regulations if he finds himself spending half his time on paperwork, and he will pay a great deal of attention to program design if he thinks the scientific merits of his research proposals are being ignored. We simply wish to suggest that each of our three actors has a different stake in federal research support and a different set of concerns. This paper attempts to adopt the viewpoint of an ideal legislator who recognizes the value of a healthy scientific enterprise, and who therefore seeks enough federal funds to produce the benefits of research that are discussed above and supports regulations and programs designed to facilitate rather than obstruct these goals.

What are some of the central issues of federal sponsorship of academic research today? The following list should provide a starting point for discussion.

The Level of Funding

In the twenty-five years following the outbreak of World War II, and especially in the decade 1958-1968, federal support to academic science grew at a tremendous rate. Federal funding of academic research projects, of research equipment and facilities, and of postgraduate fellowships expanded almost as fast as universities could absorb them. This growth faltered in the late 1960s and then

came to an abrupt halt in 1969. Measured in constant dollars, federal expenditures on academic research increased by roughly 400 percent between 1958 and 1968 for an average annual growth rate of seventeen percent; real expenditures declined in each of the next three years and, despite increases in the last three budgets, federal research spending is now barely above the 1968 peak.

The nation's universities responded to the funding growth of the fifties and sixties by rapidly expanding their research programs. By the late 1960s, the top twenty or so research universities were receiving a quarter or more of their overall operating budgets from federal research grants and contracts which supported most of the research performed there. When the funding growth ended, the research programs of these universities were severely squeezed.

The financial squeeze has been particularly severe in the provision of research facilities. In the late 1960s and early 1970s, federal spending on academic R & D plant fell to a small fraction of what it had been a few years earlier, and it remains even now far below peak levels. Universities are now critically in need of funds to upgrade inadequate and out-of-date facilities and, for the first time since World War II, one hears American researchers in a few fields speaking enviously of the laboratory facilities available in Europe.

TABLE 3

Federal Obligations* to Universities and Colleges for R & D Plant, FY 1964-1976 (dollars in millions)

FY	R & D Plant Current Dollars	R & D Plant Constant Dollars
1964	101	136
1966	115	150
1968	96	116
1970	45	49
1972	37	37
1974	29	25
1976	24	18

* Expenditure figures not available; trends are similar

The squeeze has been equally severe for the support of graduate students. Following the Sputnik crisis, the Congress decided that American higher education was not producing enough trained scientists and teachers. The response was to make a large commitment to federally sponsored graduate fellowships. From 1960 to 1968, federally funded graduate fellowships and traineeships increased from about ten thousand to nearly sixty thousand annually. This total has been declining almost without interruption since then and is now substantially reduced from its 1968 peak. Universities have been forced to substitute institutional funds for the federal dollars that

have been withdrawn -- in particular, substituting teaching fellowships for federal sponsored fellowships. With the declining levels of support (coupled with the less favorable job market that has resulted from the relative scarcity of federal research funds), graduate enrollments in the physical and mathematical sciences and in engineering have been declining steadily since about 1970. In view of demographic forecasts, and of retirement policies which may reduce the number of academic jobs open to general competition, this situation will be difficult to reverse.

The squeeze on funds for the performance of research projects has not been as severe; in constant dollars, federal expenditures on academic research never fell below ninety percent of the 1968 peak.

TABLE 4

Federal Expenditures of Universities and Colleges
for Performance of R & D, FY 1964 - 1976

FY	R & D Performance Current Dollars	R & D Performance Constant Dollars
1964	917	1235
1966	1261	1643
1968	1572	1904
1970	1648	1804
1972	1839	1839
1974	2032	1745
1976	2526	1888

However, even this small decline, and the period of no growth which followed, have had a disruptive effect on academic research. As funds became relatively more scarce (and as funding agencies awarded grants in smaller amounts or for shorter periods of time in an attempt to spread the funds further) researchers have found it necessary to divert more and more of their efforts to writing proposals for funding. With increasing frequency, investigators find their grants running out before they have acquired new sources of support, and they are forced to take the costly and disruptive step of temporarily suspending their research projects. And finally, when funds are scarce, it is particularly difficult to get support for research into unconventional topics, or research that cuts across disciplines, or research undertaken by young faculty members who have not yet established their reputations. In the fifties and sixties, when federal money was plentiful, none of these problems actively constrained academic science, for all are problems of not quite enough money at the margin, and until the late sixties there was plenty of money at the margin.

The preceding section of this paper suggested that there is a critical level of basic research funding, below which the health of the entire scientific enterprise suffers. In recent years, members of the scientific community have expressed serious doubts as to the adequacy of federal support to basic research, suggesting in effect that funding has fallen below this critical level. Certainly in some disciplines, such as high energy physics (which depends very heavily on federal funding), many researchers now feel that funding is insufficient to maintain world leadership in

all areas of research. Most research in high energy physics takes place at three FFRDCs which house the nation's major accelerators. A month ago, the director of one of them, the Fermi National Accelerator Laboratory (Fermilab) resigned his post in protest of what he considered "indecisive and subminimal" federal support which threatened the viability of Fermilab. Another of the accelerator laboratories, the Stanford Linear Accelerator Center (SLAC) is now operating at less than half of capacity due to lack of funds. And the best European facilities, such as those at the European Center for Nuclear Research (CERN), are both more powerful and more generously funded than any of the American accelerator laboratories.

High energy physics may be an extreme example, but it seems clear that researchers in most disciplines are greatly concerned about what they feel to be inadequate federal funding of basic research. The availability of federal funds is by far the most important aspect of federal research policy, not only for those investigators who are unsuccessful in gaining support for their research proposals, but also for investigators who must deal with more frequent renewals, multiple proposals to support a single project, tighter review of project budgets, and so on. And there is general agreement in the scientific community that more federal funds are needed to renew the vitality of basic research in the United States.

It is extremely difficult to determine just how much the federal government should spend on basic research, or what constitutes adequate support to academic research. Research, like health

care, is capable of absorbing almost unlimited resources, and there is no objective way to judge what the public is gaining in return for its investment in basic science. Twenty years ago, there was almost unanimous agreement in the scientific community, the Congress, and the public that the nation was not investing enough in scientific research. As late as 1960, a statement by the President's Science Advisory Committee (the "Seaborg Report") recommended that:

> Simply in terms of economic self-interest our proper course is to increase our investment in science just as fast as we can, to a limit not yet in sight.

Today, with federal expenditures on basic research in the vicinity of $4 billion annually, it is difficult to defend such a strong statement.

Whatever the level of funding, stability in funding is essential for the health of the scientific enterprise. An abrupt cutoff in federal funding, such as occurred in the late 1960s, forces research institutions to cut back on support for graduate students, faculty salaries, and research activities until the funding needed to support them is resumed. Such interruptions are very costly. Scientific research is a gradual process with a long gestation period, and an experiment often cannot simply be resumed at the point where it was left off a year before. Furthermore, any research project assembles a particular collection of scientific talent and resources which may be difficult to preserve or duplicate after a lengthy hiatus. Federal funding that increases at a pace too rapid to be sustained should also be avoided, since it induces universities to expand their graduate enrollments and research activities to levels that cannot be sustained when the pace of growth slows.

After nearly a decade without real growth in the federal research budget, federal spending on basic research has once again begun to grow in real dollars. The 1976, 1977, and 1978 budgets showed modest increases, and the proposed 1979 budget provides a five percent real dollar increase in basic research funding. Scientists and policy-makers are now debating how large the annual rate of real growth should be to maintain the vitality of the scientific enterprise, with most of the spokesmen for basic science arguing that some real growth is necessary.

It seems unlikely that the next ten years or so will see anything approaching the explosive funding growth of the 1950s and early 1960s. At the same time, it seems likely that federal funding of academic research will at least keep up with inflation, and perhaps do a little better. How much better is necessary to maintain an adequate national capacity for basic science remains an open question.

There are those in the Congress and the informed public who believe that the federal government is already spending far too much on academic research. Some of these critics simply hold that other federal programs should have higher priority than scientific research; others believe that basic research funding is in some sense a boondoggle for scientists. We close this section with the observation that the costs of spending slightly too much on basic science are far less than the costs of not spending enough. Spending too much means not getting quite as great a return from the money that is spent as could be gotten if it were spent elsewhere. Spending too little may mean compromising the health of basic science

in the United States, and damaging the international leadership in science and technology that we have enjoyed for more than thirty years.

Financial Oversight

To those who perform academic research, the level of funding is the most important aspect of federal/university relations; to those who administer academic research, the main source of concern is the body of regulations imposed on universities to ensure that federal funds are properly used. Funding agencies have historically allowed universities much more flexibility in the conduct and management of federally sponsored research than is usual for federal procurement. In recent years, however, there has been a proliferation of regulations governing federally sponsored academic research. Most university administrators (and researchers) now believe that federal oversight is far more constraining and rigidly enforced than is desirable. Moreover, the government seems to be adopting an increasingly adversarial stance towards the research universities. Funding agencies seem to be "going by the book" more than in the past, and federal audits are becoming more frequent. Many observers feel that the cooperative nature of the federal/university partnership is being lost; that funding agencies are becoming distrustful of the universities' good faith in handling federal funds; and that institutions such as peer review, upon which much of the success of academic research rests, are coming under attack.

One finds examples of federal oversight generating problems in every aspect of the research relationship. The increasing amount of

time and resources that go into preparing a research proposal were mentioned above. This is partly the result of the scarcity of federal dollars. A researcher often must submit several proposals in order to receive funding on one; this number may be further increased because grants awards are smaller and no one agency will fund his entire project; and he must start the entire process over again sooner because grants are awarded for shorter periods than in the past. But much of the burden is the result of agency requirements for extremely lengthy, detailed, and specific proposals which the researchers claim add little or nothing to the quality of the proposal, its prospects for success, or the agency's ability to evaluate it.

Regulations spelling out the steps that researchers must take to justify certain costs are complex and time-consuming and becoming more so. The purchase of large pieces of equipment, and the expenditure of federal money on travel expenses (e.g. to attend a scientific conference) are particularly difficult to get approved. Federal agencies also require extensive documentation of expenditures. The most irritating of these is "time and effort reporting" which requires that each researcher provide an accounting of the hours spent on each federally sponsored research project, despite the fact that research professors do not and cannot work on a time clock.

It is in the nature of basic research that the investigator must have the freedom to follow his or her line of inquiry wherever it may lead, even if this means sudden and unforeseen changes in the topic or in the methods of research. Ideally, the investigator

would like to be free to fly to California or to Europe to attend a conference on a subject which has suddenly become very significant, or to consult with colleagues on a recent development. He would like to be free to purchase a piece of laboratory equipment which a recent laboratory result has rendered essential. He would like to be free to work on a project by sitting and thinking about it, even though this cannot show up on a time sheet. In short, basic research is creative work which cannot be made to conform to a plan which is spelled out, in detail, in advance.

At the same time, the federal government has a legitimate interest in ensuring that federal funds are not improperly used. A federal agency should not be so heavy-handed as to assume that all academic researchers will embezzle federal funds unless prevented from doing so, nor should that agency abdicate its responsibility to the public by assuming that researchers, left entirely to their own devices and without any federal oversight, will serve as ideal stewards of public funds.

One of the most pressing needs in government/university relations is to devise some mode of oversight -- some set of regulations -- which discharges the government's obligations to exercise control over public funds without undesirably constraining the conduct of academic research. Unless such a set of regulations can be devised, the system of federally sponsored academic research is in some danger of breaking down.

For example, it has long been a practice of research universities, when the funds in one research project's account temporarily ran low, to "borrow" funds from another project's account. This

practice, which was frequently used to tide over a research project whose annual renewal was delayed by inaction of the funding agency, was followed with the full knowledge and approval of the funding agency's program officers, despite the fact that it violated agency regulations, which specify that no expenses incurred before the award of a grant may be reimbursed. In recent years, federal auditors have "discovered" this practice, and are disallowing such inter-project loans. Given the frequency with which project renewals are delayed, and the high cost of shutting down a project for a month or two until a renewal comes through, this new policy threatens substantial disruption of academic research. It is essential that some means be found to solve this and other such problems -- ideally by drawing up regulations which reconcile the researcher's need for flexibility with the government's obligation to oversee, rather than by adopting practices which circumvent government regulations.

Regulation of Research

In recent years both investigators and administrators have complained that the federal government has gone beyond purely financial oversight and now regulates the substance of research. The universities' dependence on federal funds has been used increasingly as a lever to obtain compliance with federal regulations, by making receipt of research funds contingent on compliance. While financial oversight is usually regarded simply as unproductive and burdensome, regulation of research itself is seen as threatening the integrity of the university as a place of scholarship and learning.

The most widely publicized example is the recent controversy over recombinant DNA research. The research involves inserting a segment of a DNA molecule from an organism into the DNA of an unrelated host bacterium. Since DNA contains the genetic code of an organism, the technique makes it possible to manipulate the hereditary characteristics of the host bacterium, and to create new bacteria that do not occur in nature. Since DNA is replicated when an organism reproduces, the entire progeny of the altered bacterium will retain the altered genetic characteristics of the original host.

Recombinant DNA research may lead to major technological breakthroughs in pharmaceutical production, medical practice, crop production, agricultural breeding, and even energy supply. However, critics of recombinant DNA research warn that the technique, which is practiced almost exclusively on Escherichia coli, a common bacterium in the human intestine, may produce new strains of pathogens which, if they escape from the laboratory, will cause untreatable epidemics, or upset the ecological balance. A second concern is that the technique may eventually be used for undesirable "genetic engineering" of humans.

In 1974, the foremost investigators in the new field voluntarily placed a moratorium on several types of experiments which they thought were the riskiest. Two years later, in June 1976, the National Institutes of Health released guidelines spelling out which types of experiments are judged too risky to take place, and prescribing various levels of containment for the rest, to ensure that altered

bacteria do not find their way outside the laboratory. Although these guidelines do not now have the force of law, researchers must observe them in order to receive federal funds, and several states and localities, as well as the federal government, have considered (and in a few cases passed) legislation to prohibit certain types of DNA research.

The general (although not quite unanimous) view of the scientific community is that recombinant DNA research does not present any extraordinary risks. The biochemistry of E coli, and therefore of any variants of E coli that might be produced in the laboratory, is quite well understood. Both the scientists engaged in DNA research, and biologists and public health experts who have no stake in the research, agree that the odds that gene-splicing will produce new pathogens that cannot be controlled by conventional means are extremely small, and that in any event the methods of containment currently in use are more than adequate to protect against the release of altered organisms from the laboratory. They conclude that recombinant DNA research is no more dangerous than research on more conventional pathogens that is routinely conducted without government controls.

The recombinant DNA debate has generated considerable concern over the role of the federal government in deciding what research shall take place and what research shall not. Many scientists strongly believe that this decision should be reserved for the scientists engaged in the research, who are in the best position to assess both the risks and the potential benefits of experiments; and that federal exercise of this prerogative, especially in a

nascent field such as recombinant DNA research, will be very damaging to the progress of science. Even more disturbing to them is the notion, which underlies some of the opposition to recombinant DNA research, that some research should be banned, not because the experiments are risky, but because the resulting knowledge might be dangerous.

A second area in which the government regulates academic research is experiments on human subjects. The Department of Health, Education, and Welfare requires any institution conducting DHEW-funded research on human subjects to set up a committee on human subject research and to submit each such research project for review by the committee. DHEW further requires that informed consent to the experiment must be obtained from any human subject who may be exposed to physical, psychological, sociological, or other harm.

There is a genuine public interest in ensuring that researchers are properly solicitous of the welfare of human subjects, and also in guaranteeing the right of human subjects to know how experimental procedures will affect them. However, the DHEW regulations do add to the cost of conducting research on human subjects and, more important, they can make it difficult or impossible to conduct unbiased randomized experiments, or experiments which by design conceal from the subjects the object of the experiment. Thus the regulations can effectively prevent certain experiments from taking place, and detract from the scientific merit of others that are allowed. The important policy issue is whether there is an adequate mechanism to balance these competing interests.

A third area of government regulation involves classified research. In particular, the forced classification of basic

research projects raises serious issues of academic freedom. On several occasions the Atomic Energy Commission (now the Nuclear Regulatory Commission) has classified a civilian investigator's work on laser fusion. More recently the Energy Research and Development Administration classified a lecture on nuclear fusion given by a Soviet physicist, going so far as to confiscate a blackboard used in the lecture.

This past fall, the Institute of Electrical and Electronics Engineers announced a symposium on the use of computers in cryptology, including recent advances in pure mathematics that can be used to devise virtually unbreakable codes. This prompted an employee of the National Security Agency to warn IEEE that the Symposium might be subject to classification under the Arms Export Control Act, and that researchers who discussed these topics publicly might be violating the Act. After obtaining legal advice, the IEEE decided to proceed with the symposium, but several participants chose to suspend distribution of their papers on computer cryptology, and a number of graduate students who were to present the results of their research at the Symposium were advised to let their professors make the presentations instead. Even when not carried out (the NSA took no action in this case), such threats tend to restrict the dissemination of research findings, and ultimately to induce investigators to choose less controversial research topics. Moreover, classification of research rarely achieves its purposes. More often than not, one investigator's research can be duplicated by another, even if the latter has only the most sketchy information on the former's work, since they both have the

same body of knowledge to draw upon and the same ability to recognize the implications of that knowledge for a specific problem.

The IEEE case is a good example of this. Several countries support theoretical work in mathematics at the same level of sophistication as the United States. In any of these countries, (including Russia) there are mathematicians familiar with the theory used to devise the unbreakable codes (the theory of one-way trapdoor functions) who would need only the information that the theory had been used for this purpose to be able to devise their own equivalent unbreakable codes in a short period of time. The same principle applies to theoretical work on nuclear fusion; secrecy cannot prevent researchers in other countries from rapidly duplicating research by American scientists, even if it is classified. (This principle does not, however, extend to development work, where the design of specific hardware can be kept secret for a relatively long period of time.)

Fortunately, forced classification of basic research has occurred quite infrequently. Most work that is classified is applied research and development on explicitly military topics, with the investigator consenting to secrecy in advance. Such work does not depend on the broad dissemination of results in the way that basic research does. As long as the scientific community is in general agreement with the government policies that the classified work seeks to advance, academic researchers tend to accept classification of applied military research. When this consensus in favor of government policy breaks down, as it did during the Vietnam War, academic support for classified research tends to break down, but this is more a question of the unwillingness of researchers to work

for unpopular agencies than of violations of academic freedom. At present, the general consensus of the academic community is that no serious problems are posed when an investigator voluntarily agrees to secrecy in order to receive support for a military research project.

The recent controversy over past CIA sponsorship of academic research on drugs, hypnosis, brainwashing, and other related topics has raised questions similar to those involved in classification. The CIA channeled its research funds through dummy research centers to conceal the source of support. The revelation of CIA sponsorship in the press has prompted some discussion of the importance of full disclosure of the sources of research support, but once again, this is as much an expression of the unpopularity of working for the CIA as it is an issue of government control of the substance of research.

These are among the most notable examples of federal regulation of academic research. Some other examples, such as federal issuance of licenses to use radioactive materials in research, are not controversial because they do not significantly interfere with the conduct of research. Others, such as the subpoena of a social scientist's research notes for use in a civil proceeding, have arisen only a few times and have not received a great deal of attention, although they might become lively issues in the future.

What is at issue in all these cases is not whether public health, safety, and welfare are legitimate public policy objectives, nor whether the federal government has the power to make laws that further these objectives, but rather whether regulating the substance

of academic research is the best way to achieve them. Many researchers argue that they are in a better position than civil servants in Washington to decide what research is dangerous and how to limit the danger. And there is a strong sentiment that government regulation of academic research, especially where the regulation is aimed at non-scientific objectives, undermines academic freedom and threatens the health of American science.

Cost Sharing

An issue which is of great importance to universities in their dealings with the federal government is whether the federal government should bear the entire cost of federally sponsored research, or whether universities should be required to share the cost.

During World War II, OSRD had a policy of reimbursing universities for the full cost of contract research, including an appropriate share of overhead costs. This policy continued to govern federal research support through the 1950s and early 1960s. In recent years, however, the tendency has been to disallow an increasing number of indirect costs. Furthermore, since 1966, HEW, which accounts for more than half of all federal support of academic research, has required universities to share in the cost of its research grants, usually by accepting less than full reimbursement in indirect costs.

The amount of attention paid to the cost-sharing requirements is closely tied to the overall level of federal support. As long as the volume of grants and contracts was growing rapidly, research universities were sure to receive more federal money for overhead

costs each year; the increase in volume swamped the trend towards greater cost sharing. When this growth in funding ended in the late 1960s, the dropoff in overhead payments squeezed institutional budgets, and cost sharing became a major concern of university administrators.

The issue of cost sharing has been associated with the debate over the use of research contracts versus research grants. Historically, contracts were awarded for research which served specific federal needs and for which the government was willing to pay the full cost, while grants were used as subsidies to research considered to be in the general public interest. This distinction between the contract for the purchase of services and the grant-in-aid is still widely regarded as a basis for full reimbursement on contracts, and cost sharing on grants. However, the practical distinction between contracts and grants is now small. Grants and contracts are used more or less interchangeably in the support of academic research, and the General Accounting Office has ruled that acceptance of a research grant creates an implicit contract between the university and the funding agency. Grants and contracts are still governed by different bodies of regulations, but the notion that there is a logical link between the choice of a grant or a contract and the obligation for full reimbursement is no longer very compelling.

Some university administrators claim that requiring universities to share in the cost of federally funded research projects has a parasitic effect on other university activities. Since the university does not receive enough federal funds to cover fully the costs

of research, it must withdraw funds from other activities - for example, by cutting the budgets of other departments - in order to finance government research projects.

This argument is convincing when applied to most non-medical applied research projects and all development projects, since they are undertaken as a service to the government and yield little or no benefits to the university. But there is nothing in the logic of federal support to basic research, or to applied medical research, that suggests that the federal government must bear the entire cost. These activities produce benefits both for the federal government and for the university, and it is not unreasonable to regard federal support as a grant-in-aid, whatever funding instrument is used, and to expect universities to bear some of their cost. As to the claim that university cost-sharing has a parasitic effect on departments which do not receive federal research funds, it would be as reasonable to argue that federal funds which share the cost of university research increase the resources available for other university activities.

Whatever the merits of these conflicting views, it remains true that the perception that federally-funded research draws resources away from other university activities has created a certain amount of friction between departments that perform federally sponsored research and departments that regard sponsored research as a drain on university resources.

We turn now to issues of the design of federal research programs. These issues are important to academic researchers and

administrators, but they are not as great a source of pressure on the system as the issues discussed above.

Allocation of Research Funds

In principle, federal funds should be allocated among fields of research, and among individual research projects, so that an additional dollar spent on any research project buys the same increase in social benefits. Because the benefits of research are so hard to measure, this prescription is almost completely useless in practice.

An agency disbursing research funds simply has no objective way to decide how much to spend on the various disciplines or how much to award to competing proposals. At the same time, it cannot refrain from making allocative decisions, nor can the Congress, in deciding how much money to appropriate for the various agencies which fund research. It is often argued that given the uncertainty of which projects and which fields of basic research will pay off, funding agencies should adopt a neutral policy, accepting the subjective judgment of the scientific community as to which research merits support. Accordingly, most major funding agencies rely largely on unsolicited research proposals from non-government (largely academic) researchers, which are then reviewed by the researchers' scientific peers. It is hoped that those fields of research which have the greatest promise for scientific advance will generate a greater volume and higher quality of research proposals, so that an agency responding to "proposal pressure" will approximate the ideal allocation described above.

While peer review of unsolicited research proposals is perhaps the best system that can be devised to choose between competing proposals in the same field, it is a mistake to think that it achieves a neutral selection of research projects. First, "proposal pressure" responds to the amount of funding, because the availability of money, which makes it possible to undertake ambitious research projects, is a large determinant of which fields are interesting and which are not. Therefore, researchers and graduate students will migrate to a field which is heavily funded, increasing the number of proposals that are received in that field.

Second, because of the divergence between the motivations of research scientists and research-funding agencies -- the former pursuing scientific knowledge, and the latter pursuing the social benefits of research -- even an ideal peer review system will not necessarily allocate research support so as to maximize the social return to research.

This is not to say that a neutral allocation of research support is not a desirable goal, or to recommend that the program officers at agencies which fund basic research should select projects or favor fields of research on the basis of expected societal gain. Since the allocation of research support principally involves judgments of scientific merit, it is probably best left in the hands of scientists, rather than being decided by government officials on non-scientific grounds. And we have considerable sympathy with the view, expressed by the Seaborg Report, that:

> Nothing could be more unwise than an effort to assign priorities or judge results in basic research on any

> narrow basis of immediate gain. It is the advance of science as a whole on which we must rely, for material as well as other returns.

Peer review governs the selection of competing proposals received in the same discipline by a single agency. The allocation of support among disciplines depends largely on how much money the Congress appropriates for the various funding agencies, and for the various research programs within each agency. Since NIH is involved almost exclusively in the life sciences, DOE (ERDA) in physics, and so on, the pattern of federal funding by discipline is closely related to the distribution of funds among agencies, with the life sciences accounting for more than half of the total at universities and colleges, and physics and engineering for more than 80 percent of the total of FFRDCs.

Finally, there is the issue of allocating funds between basic research on the one hand and applied research and development on the other. As research becomes more basic, the social benefits of research become more uncertain and recede further into the future, and the results of research become more abstract, more esoteric, and more incomprehensible to the layman. And it is the nature of politicians and professional bureaucrats that they prefer tangible, sure, and immediate benefits in areas which they can understand. There is, as the Bush Report suggested in 1945:

> a perverse law governing research: Under the pressure for immediate results, and unless deliberate policies are set up to guard against this, applied research invariably drives out pure.

This is manifested not so much by a lack of support for basic research (although it can be argued that the federal government, which in fiscal year 1975 spent $3 billion on basic research and $15 billion on applied research and development, underinvested in basic research), as by a tendency to favor "targeted research": basic research which can be related to the mission of the funding agency.

The National Science Foundation is exceptional in this respect. It was established with the explicit goal of supporting basic research in all fields of science. In contrast, the National Institutes of Health in HEW, NASA, the Office of Naval Research, and other major funders of basic research are mission agencies which support basic research principally in the expectation that the results of the research will aid them in carrying out their missions. This has three consequences. First, each agency supports only a narrow spectrum of research: NIH funds research in the life sciences, DOD in the physical sciences and engineering, EPA in environmental sciences. Second, these agencies support far more applied research and development than basic research; in fiscal year 1975, basic research made up 82 percent of NSF's research budget, but only 28 percent of NIH's, 12 percent of ERDA's, 8 percent of NASA's, and 3 percent of DOD's. And third, the mission agencies are reluctant to undertake basic research which bears no clear relation to their mission, and tend to focus their basic research programs on specific social goals, even when this does not make sense on either social or scientific grounds.

TABLE 5

Federally-Financed R & D Expenditures in Universities, Colleges, and University-Administered FFRDCs, by Character of Work and by Field of Science, FY 1975
(dollars in millions)

	Universities and Colleges	University FFRDCs	Total
Total	2284	983	3267
Basic Research	1691	307	1997
Applied Research	516	345	861
Development	78	331	408
Physical Sciences	285	531	816
Mathematical Sciences	65	61	126
Engineering	260	278	537
Environmental Sciences	181	56	237
Life Sciences	1238	43	1281
Psychology	61	0	62
Social Sciences	140	1	141
Other Sciences	56	12	68

Pressure for more mission-oriented research can also come from the Congress. The Mansfield Amendment, a rider on the Defense Department's 1970 Authorization Act, specified that "none of the funds to be appropriated by this act may be used to carry out any research project or study unless such project or study has a direct and apparent relationship to a specific military function or operation." Although the amendment was only in effect for one year, it had a lasting effect in curtailing fundamental basic research at DOD, and to a lesser extent at other agencies as well.

The most notable example of the tendency to favor targeted research is the "war on cancer" which was declared in 1971. (The origins of the war on cancer are discussed in Appendix A of this paper.) The National Cancer Institute, established in 1937, was the first of the National Institutes of Health, and has always had the largest amount of money at its disposal. In 1971, however, a decision was made to increase funding of cancer research dramatically, and to mobilize the life sciences research community to produce a cure for cancer in a relatively short period of time. Between 1971 and 1975, the National Cancer Institute's budget (measured in constant dollars) increased 132 percent, while the combined budgets of the other twelve institutes in NIH increased by only 11 percent. A number of national cancer laboratories were established, and research was pressed forward in those fields of biology and chemistry which were expected to produce a cure for cancer. During the past seven years, large numbers of researchers and graduate students who would normally have worked in other areas have been

drawn into cancer-related fields of research, finding that this was the only way to get research support.

A great deal of first-rate basic research was performed in the course of the war on cancer, but it did not succeed in making large strides towards a cure. Critics of the war on cancer have claimed that in the rush to expand the cancer research effort, a certain amount of inferior research was also supported, while research in those fields of biology and biochemistry which were not favored by the war on cancer has declined.

The RANN program (Research Applied to National Needs) within the National Science Foundation is another example of the tendency towards applied research. Established in 1968, RANN accounted for 13 percent of the NSF budget in fiscal year 1974. Much of the research supported by RANN was not highly regarded, and after budget reductions in 1975 and 1976 the program was virtually terminated in 1977. Now reorganized as the Applied Science and Research Applications Directorate of NSF, the program received a large percentage increase in the 1979 budget proposal, which would bring it back up to nine percent of the overall NSF budget.

The Breadth of Support

One consequence of the peer review system is that a relatively small number of elite institutions receive the lion's share of federal research funds. Peer review is designed to single out the best researchers for support. Since research talent is heavily concentrated in a small number of prestigious universities, reliance on peer review results in a policy of federal support to the "rich".

There are approximately 1800 four-year colleges and universities in the United States. In FY 1975, roughly 600 of them were awarded federal research grants or contracts. Thirty out of the 600 received as much federal money for the performance of research as all the others combined. (Since NIH provides over half of all federal support, universities with medical schools are heavily represented at the top end of the list.)

Federal research funds are geographically concentrated as well. In FY 1975, three states -- California, New York, and Massachusetts -- accounted for 35 percent of all federal funds for the performance of academic research.

The United States has always had a strong tradition of distributing the resources of society widely, rather than conferring them on a select group of individuals or institutions. The peer review system conflicts sharply with this tradition, and there are many who consider the system, and the concentration of support that it produces, to be totally unjustified. They feel that if the federal government is to support institutions of higher education, it should support all institutions, and that it should in large measure support them equally. This view has a considerable number of adherents in the Congress, where the geographical concentration of support might reasonably be expected to gain few supporters and many opponents. The Congress has been the source of considerable pressure to "democratize" the merit system of awards, or to replace peer review with formula grants which spread federal support more evenly.

TABLE 6

Obligations of Selected Federal Agencies for On-Campus Research and Development, to the 50 Universities and Colleges Receiving the Largest Amounts, FY 1975
(dollars in millions)

U.S. TOTAL: 2223

1	MIT	69	26	U. Miami	23
2	U. Washington	60	27	U. Colorado	22
3	Stanford	58	28	Purdue	21
4	UCLA	54	29	Cal. Tech.	21
5	Harvard	49	30	Ohio State	21
6	UCSD	49			1108 = 50%
7	Columbia	48			
8	U. Wisconsin Madison	46	31	Penn. State	20
9	U. Pennsylvania	43	32	UC Davis	20
10	Johns Hopkins	41	33	U. Utah	20
		516 = 23%	34	UNC Chapel Hill	19
			35	Case Western Reserve U.	19
11	Berkeley	40	36	Northwestern	19
12	U. Minnesota	40	37	Baylor College of Medicine	19
13	Cornell	40	38	Michigan State	18
14	U. Michigan	38	39	U. Pittsburgh	18
15	U. Chicago	38	40	U. Iowa	17
16	Yale	37			1295 = 59%
17	U. Illinois at Urbana	34			
18	UCSF Medical Center	34	41	U. Florida	16
19	Washington U. (St. Louis)	31	42	Colorado State	16
20	USC	28	43	Princeton	16
		875 - 39%	44	U. Arizona	16
			45	CUNY Mt. Sinai	16
21	NYU	28	46	U. Hawaii Manoa	15
22	U. Rochester	25	47	U. Alabama at Birmingham	15
23	Yeshiva	25	48	Woods Hole	14
24	Duke	24	49	U. Texas Anderson Hospital	14
25	U. Texas at Austin	23	50	U. Md. College Park	14
					1446 = 65%

The scientific community, along with most historians and sociologists of science, respond that scientific research is, by its very nature, an elite activity. Very few individuals are capable of producing first-rate science, and they congregate in a very few institutions. The supporters of the merit system argue that if the federal government wishes to promote scientific excellence, it has no choice but to concentrate support on the best, most prestigious, and most elite institutions. They point out that although federal research support is fairly heavily concentrated in a few institutions,scientific talent is even more heavily concentrated. For example, California, New York, and Massachusetts, which account for only twenty-two percent of the nation's population, receive thirty-five percent of federal funds for academic support. However, the same three states account for fifty-three percent of members of the National Academy of Sciences (more precisely, fifty-three percent of all members employed at universities and colleges), which should be a reasonable measure of the distribution of scientific talent. Similarly, the ten universities which receive the largest amounts of research support account for twenty-three percent of the federal dollars, but forty percent of Academy membership. This suggests to some observers that more, rather than less, federal money should be placed at the top universities.

One of the strengths of the peer review system is that by making awards on the basis of the scientific merits of individual projects, it avoids having to make explicit and politically vulnerable choices between University A and University B. The system

can be defended in terms of the objectivity or neutrality of its awards in a way that a program of block grants to the two dozen universities could not.

The proponents of peer review have also advocated programs which extend support to the second rank of research universities. The largest such program was the NSF University Science Development program of the late 1960s, which is described on page 62. Certainly the number of institutions at which a large amount of first-rate research is performed has increased significantly in the past thirty years, from perhaps as few as a dozen just after World War II, to several times that number today. This expansion in the nation's capacity for basic science has strengthened the scientific enterprise as a whole, and it is not clear whether we yet have enough centers of scientific excellence. Some observers would argue that the relatively large amount of federal research money -- over half of the total -- which goes to universities below the top two dozen or so constitutes support to second rank universities which might not be justified by a strict assessment of merit. Others advocate efforts to broaden the base of science, arguing that the health of basic research and the inflow of new scientific talent cannot be sustained if research is conducted at only a handful of institutions. Further, there may well be a minimum dispersion of funds necessary in a democratic polity to maintain the support of science.

Many observers feel that the peer review system is now coming under particularly sharp attack, and that a real possibility exists that Congressional and public displeasure with the merit system will lead to its dismantling. It does appear that the increasingly adversarial

relationship between government and academia is creating a general distrust of academic institutions, but whether the pressure on peer review is significantly greater now than in the past is very difficult to say.

Centralized Planning of Research

Academic research is supported by at least ten different cabinet departments and six other agencies, and often by several distinct offices within the same agency. Periodic attempts have been made to coordinate the policies of these agencies by conferring upon one government body or another the authority to formulate comprehensive federal research policy (NSF was originally intended to serve this role), but none of these efforts has taken hold.

This decentralization of research support is mirrored in the Congress, where each agency's research program is reviewed by a different set of authorizing, appropriations, and oversight committees. The Office of Management and Budget does provide an annual analysis of the proposed federal budget for R & D (Special Analysis P of the Budget), but this has little effect on the appropriations process.

Attempts to establish centralized research planning have run into opposition from members of the scientific community on the grounds that it will allow government officials to exercise an undesirable degree of control over the direction of research. Here it is important to distinguish between the allocation of funds among competing projects in the same discipline, and among different

disciplines. A strong case can be made that funding agencies should rely entirely on the peer review system in selecting individual projects. But peer review offers no guidance in allocating funds among disciplines, and funding agencies cannot avoid deciding how much money they will spend on physics and how much on biochemistry. It is inevitable that the federal government, in assuming most of the cost of academic research, will to a large extent control what research takes place. Centralized planning may be a reasonable way to provide a rational basis for deciding how much the federal government should spend on research, and how federal funds should be divided among the various disciplines.

From time to time a proposal has arisen in the Congress or the Executive branch that goes a step beyond centralized planning, recommending the establishment of a single agency to administer all federal research programs. Usually the recommendation is for a cabinet-level Department of Science. The Department of Education, currently being advocated by the Carter administration, at least in some of the versions that have been discussed, would bring many of the agencies supporting basic research under a single roof.

It is difficult to predict the consequences of centralizing the administration of federal research support without knowing the specific details of the reorganization. One weakness of such a move would be that it would concentrate control over federal research funding in the hands of a single bureaucracy. If the agency decided on severe cuts in expenditures on astrophysics, for example, astrophysicists would have no alternative source of support. For

TABLE 7

Federal Obligations to Colleges and Universities and FFRDCs for Performance of Research and Development, by Agency FY 1975

(dollars in millions)

Agency	Colleges & Universities	FFRDCs	Total
TOTAL	2257	1078	3335
Agriculture	109	-	109
Commerce	22	*	22
Navy	89	110	199
Air Force	58	86	144
Army	38	-	38
Other DOD	5	1	6
ERDA	119	617	736
EPA	34	-	34
NIH	1047	3	1050
Other DHEW	148	-	148
HUD	2	-	2
Interior	27	*	27
Justice	10	-	10
Labor	4	*	4
NASA	109	217	326
NFAH	8	-	8
NSF	398	44	442
State	8	-	8
DOT	21	*	21
Veterans Administration	1	-	1

* less than 1

this reason the scientific community tends to favor a decentralized, "pluralistic" system of support in which several agencies fund projects in the same disciplines and researchers are not at the mercy of a single agency. On the other hand, centralized administration of funds may be the only way to achieve centralized planning, and a more rational allocation of federal research support.

An objection that is more difficult to answer is that centralization would increase the vulnerability of the system to Congressional reductions in research funding, creating a single jugular vein that could easily be cut. Finally, the goal of increasing the attention given to scientific research in the formulation of the federal budget might be frustrated if research became subordinated to other components of a Department of Science and Education.

Mechanisms of Support

All federal agencies which fund academic research rely heavily on the project grant or contract as the mechanism of support. (The project grant is described in some detail in Appendix B of this paper.) The project grant is an effective mechanism for providing support to individual research projects, but there is room for experimentation with alternative funding mechanisms which would fill some of the gaps in academic research needs which the project grant as currently practiced cannot easily cover. The project grant procedure begins with an investigator submitting a proposal for a specific research project to a funding agency. The proposal includes a fairly detailed budget, giving indirect

(i.e., overhead) costs as well as direct costs. The proposal is reviewed by a group of the investigator's scientific peers. Based on their evaluation of the proposal's scientific merits, (and on the availability of funds in the budget), the funding agency decides whether to fund the project. Funding is usually for a period of from one to five years. The investigator is required to submit progress reports during the course of research and a final report upon completion; and he also must comply with a number of other reporting procedures and requirements. Since research projects typically run longer than the period of the award, the investigator must periodically submit proposals for award renewal, which are usually, but not always, approved. A mechanism which abruptly cuts off support to a research project when the period of its grant runs out disrupts the research process by making it necessary for investigators to curtail or terminate their research until they can find other sources of funds. The funding agencies make every effort to provide uninterrupted support for sound research projects, and the most highly regarded researchers routinely are awarded new grants when their old ones run out. However, given the large number of investigators competing for limited funds, some number of grants must be cut off each year.

This problem is most severe when grants are awarded only for a single year. Besides increasing the amount of effort that investigators must expend in preparing and submitting research proposals, single-year funding creates the risk that a project will have to be terminated in any given year, due to lack of funds.

Most agencies recognize this problem and award a large portion of their funds in the form of grants running for two or more years. However, by committing funds for several years in advance, agencies leave themselves with less discretionary money in any given year. Some agencies deal with this problem by committing funds to support a project only for a single year, but assuring support in succeeding years conditional only on the agency's receiving sufficient appropriations from the Congress. And multi-year funding only reduces, but does not eliminate, the frequency with which researchers must submit new proposals and risk the abrupt termination of the projects.

NASA has adopted a mechanism known as "step funding" which smooths the process of terminating a project. Rather than being cut off abruptly, NASA grants are phased out over a three-year period. Step funding increases the amount of funds that an agency commits itself to spending when it awards a grant, but it also permits a more orderly termination of projects. A more sophisticated version of step funding, known as "roll-forward funding," awards full support for the first year of a grant and a decreasing fraction of support for the several succeeding years. For example, roll-forward funding could commit funds for full support of a research project in year one, two-thirds support in year two, and one-third support in year three, for a total equal to two full years of support. In year two, one full year of support is awarded, but this amount is divided equally among years two, three, and four, and this procedure is followed in each succeeding year. Thus, as long as the project is approved, it receives full funding, and

if and when the agency decides to stop funding the project, funds are already committed for gradually phasing out the project over a two-year period. Roll-forward funding has not, to our knowledge, been used by any agency which funds academic research, and it would probably be difficult to implement because of the required initial double appropriation.

Project grants support only a single type of research activity: well-defined experiments by established investigators. Research activities which cannot be neatly parcelled into projects cannot conveniently be funded by this mechanism of support. In particular, universities require funds to purchase equipment and facilities used by a number of investigators working on different research topics; to support young scientists in their first year or two of research until they can get funding on their own; to tide over investigators who are between grants; to fund innovative research that fails to get support; and to cover expenses of federally-funded projects that the government either does not reimburse (i.e., disallowances), or reimburses only after an excessive delay.

Some, but not all of the gaps left by project grant funding are filled by junior and senior fellowships and by equipment grants. In 1975, federal agencies supporting academic research awarded $200 million in fellowships, traineeships, and training grants, and $45 million in grants and contracts for R & D plant -- compared with $2.2 billion for research projects, both large and small.

Some agencies have made use of funding mechanisms that award a single grant to a number of investigators working on different projects, thereby both reducing the administrative workload of

administering the grants and giving the recipients some discretion in the use of the funds. These mechanisms can be referred to in terms of the unit of research used as the basis of aggregation, as "institutional grants," "departmental grants," and "center grants."

The simplest method of aggregating research support is to award a single grant to an entire univeristy, to be used at its discretion in support of research. This form of support is known as an institutional grant, and it was used by NSF to a limited extent in the 1960s. Although they also reduced the administrative workload of both universities and funding agencies, institutional grants were justified almost entirely on the basis of helping universities meet research expenses that were missed by project grants. Accordingly, most proposals for institutional grants have been based on a formula which would award funds to each university in proportion to the amount of federally-funded research conducted there.

In recent years, there have been periodic moves in the Congress to reestablish institutional research grants, largely in response to pressure from first rank research universities to provide more comprehensive support to academic research. The initial proposals have been for formula grants which would award each university an amount in discretionary funds proportional to the amount of funds it receives in project grants. As each bill moved through the Congress, the wider community of higher education insitutions has exerted pressure to adopt a broader program of

institutional support which would have the effect of loosening the hold of the largest research universities on federal funds, and this altered form of institutional support has consistently failed in the Congress. As we noted above, the peer review project grant system, which awards most support to a few elite institutions, is relatively immune to political attack on "democratic" grounds; institutional grants do not share this immunity.

Departmental grants are similar to institutional grants, but at a lower level of aggregation; they are unrestricted grants to a specific department within a university. Center grants are similar awards to an individual laboratory or research center, providing unrestricted support to a group of investigators working together on a common set of research topics. Both NSF and NIH award some departmental and center grants, usually using them to provide a foundation of support which is supplemented by project grants to the individual investigators within the department or center.

The Federally Funded Research and Development Centers are funded by center grants on a grand scale. Typically, a single agency will provide several tens or even hundreds of millions of dollars to cover annual operation and construction costs of the center, including staff salaries. The amount of support, and the allocation of the funds between operation and construction, is determined by negotiation with the agency with consultation from the broader scientific community.

Department and center grants are attractive funding mechanisms. By combining support for a number of investigators, they reduce

the effort that must go into proposal preparation and review and grant administration. By using a single department-wide or center-wide grant, they allow the central administration of the department or center to assume the burden of negotiating support, whereas the project grant system places much of this burden on individual investigators. And they place decisions regarding the use of funds in the hands of those who are most familiar with the work that is undertaken, and who are therefore regarded as most competent to judge which work deserves support.

The great strength of the project grant system is its use of peer review to choose between competing research projects on the basis of scientific merit. Department grants and center grants cannot benefit from peer review as this term is usually understood, because the grant does not identify in advance specific pieces of proposed research that can be judged on their merits. However, at least at the larger laboratories supported by center grants, scientists must defend the scientific merits of their work before their colleagues in order to receive approval for a project using the center's resources. It is widely conceded that the research conducted at FFRDCs is of the highest quality, in part because it benefits from this internal peer review, as well as from conventional peer review of the grants that support individual projects conducted at the centers.

There can be a "free rider" problem, especially for department grants and smaller center grants; it is difficult for a group of scientists to refuse all support to a relatively unproductive colleague. And like institutional grants, department and center

grants may be difficult to defend politically against the advocates of a wide distribution of federal research support, especially if they are undertaken on a large scale. The effective use of federal research support, whatever funding mechanism is used, depends on concentrating the support on a relatively small number of first-rate investigators. Because of its disaggregated nature, the project grant mechanism makes it possible to do this, while still awarding some amount of federal funds to a fairly large number of schools. Department and center grants are more vulnerable to the criticism that they serve to strengthen the most prestigious research institutions -- that they "make the rich richer."

This last concern has prompted many government and independent studies of academic research to recommend government action to increase the number of first-rank research institutions, usually by calling for programs that concentrate federal research funds on universities that are just below the first rank. The NSF undertook such a program in the late 1960s; between 1965 and 1972, the University Science Development program spent a total of $177 million to upgrade the quality of research at thirty-one universities.

Such programs require a massive amount of funds if they are to make any significant impact. The NSF program spent an average of only $5.7 million on each institution, and one must assume that much more than this is needed to bring a university into the first rank of research institutions. However, such programs are under great political pressure not to limit their awards to a few schools, and it is unlikely that Congress would appropriate sufficient funds

to provide a meaningful level of development support to a large number of universities.

Three other support mechanisms deserve brief mention.

The Office of Naval Research has, since its inception, used an award mechanism which reduces its administrative workload. ONR periodically (usually once each year) negotiates a "basic contract" covering all ONR-sponsored research at a given university. Individual projects are then governed by "task orders" which specify each project's scope and budget. This procedure reduces the amount of effort that must be spent in negotiating the terms of research contracts, but does little to reduce the burden of preparing and processing the individual proposals, and other agencies have not adopted it.

Regranting, which has been discussed and rejected by NSF, would involve designating an intermediate authority, such as a university or a group of universities, to which the funding agency would delegate the task of selecting individual projects to receive support. It would preserve most of the character of the project grants (including, perhaps, a formal peer review) while shifting some of the administration of grants from the agency to the universities, who presumably would be able to handle it with less red tape. There would probably be problems, however, with delegating this authority to a non-government body.

The third mechanism has not been seriously considered by any funding agency. It would provide support for academic research activities that fall in the gaps between project grants by including some amount of discretionary funds in the budget of each

project grant, as a kind of "research overhead." This practice is modeled on the "independent research and development" funds that are included in military procurement contracts to industrial firms. Its strength is that it would bypass the problems that face institutional and departmental grant programs in deciding how much money to give to which schools, and it would share the project grant's relative immunity to political attacks on the distribution of support. On the other hand, research overhead would add substantially to overhead rates for academic research, and the increase in overhead rates has already been the source of Congressional dissatisfaction.

We mentioned earlier that university investigators and administrators are far more concerned with the level of funding and the amount of federal regulations than with the design of the system that supports academic research. These two factors, and particularly the perceived inadequacy of funding, are the sources of most of the pressure on the academic research enterprise. If funding levels were somehow increased and federal regulations were somehow relaxed, academic institutions could return to dealing with a system of research support that has served them well since World War II, and with which they are very comfortable.

Yet there is probably room for improvement in the planning, allocation, and administration of research funds, as discussed in the last four subsections of this section. It may be that academic researchers and administrators, in their preoccupation with funding levels and regulations, and their desire to relieve the

day-to-day pressures on the performance of research, underestimate the value of such improvements in design. The scientific community generally seeks to preserve the existing system of federal research support -- peer review, decentralized funding, the project grant -- because this system has worked well for them in the past. On the short run, this is probably the best course of action, but on the longer run it may be important to tinker with the system to improve it, and permit it to adapt to a changing world.

APPENDICES

APPENDIX A

A BRIEF HISTORY OF FEDERAL SUPPORT TO ACADEMIC RESEARCH

From the perspective of the 1970s, it is difficult to recall the attitude toward extramural support of academic research that prevailed before World War II, or to appreciate how great was the transformation of American universities that resulted from the massive postwar infusion of federal funds. Until the late 1930s, the federal government showed little interest in supporting basic academic research. The universities, for their part, placed a high value on academic integrity and autonomy, and avoided government patronage which, it was thought, would bring with it government interference and control. As late as 1934, Karl T. Compton, president of the Massachusetts Institute of Technology and head of the President's Science Advisory Board, tempered an appeal for federal research grants with the following words:

> I confess to considerable doubt as to the wisdom of advocating federal support of scientific research....If government financial support should carry with it government control of research programs or research workers, or if it should lead to political influence or lobbying for the distribution of funds, or if any consideration should dictate the administration of funds other than the inherent worth of a project or the capabilities of a scientist, or if the funds should fluctuate considerably in amount with the political fortunes of an administration or the varying ideas of Congress, then government support would probably do more harm than good.

There had been a long history of support for agricultural research, beginning with the Morrill "Land Grant" Act of 1862, and supplemented by the Hatch Act of 1887, which awarded formula grants to land grant colleges, and the Smith-Lever Act of 1914, which appropriated additional funds for agricultural colleges.

In 1915, the Advisory Committee for Aeronautics (later renamed the National Advisory Committee for Aeronautics, or NACA) was established to conduct research into the problems of flight. NACA, which was absorbed by NASA in 1958, was the first federal agency to award contracts for individual research projects at colleges and universities.

The emphasis of both NACA and the Hatch and Smith-Lever Acts was on applied rather than basic research. This accorded with the view, endorsed in 1903 by a Presidential Committee on Organization of Government Scientific Work (and restated in 1908 by a committee of the National Academy of Sciences), that science "on the part of the Government should be limited nearly to utilitarian purposes evidently for the general welfare." But, as the cost and complexity of scientific research escalated rapidly in the 1920s and 1930s, the notion of federal support to basic research began to gain favor. A Science Advisory Board, created by President Roosevelt in 1933, and chaired by M.I.T. president Karl T. Compton, proposed in 1934 that the government spend $16 million for scientific research over the following six years. And in 1938, the National Resources Committee, chaired by Harold Ickes, released a report entitled Research, a National Resource, which estimated annual federal support of academic research at $6 million (out of a total academic research budget of $50 million) and called for an increase in federal funding of basic research.

On the eve of World War II, a small amount of federal funds began to flow to basic academic science. The National Cancer Institute was established in 1937, and was authorized to make grants-in-aid for academic research. During its first three years of operation, it awarded $220,000 in grants, not all to colleges and universities. In

the same years, the Works Progress Administration supported a few dozen research projects in mathematics, physics, chemistry, and astronomy. But this modest increase in federal funding was swamped by the wartime research effort, which had a greater impact on academic science than any other event, before or since.

Prior to World War II, the United States lagged far behind Europe in scientific achievements, and especially in theoretical research; bright young American scientists would be advised to spend a year or two in Europe in order to be exposed to the best minds in their fields. This balance began to shift in the 1930s, due in part to the rise of Hitler and Mussolini and the purges of Stalin which induced many leading European scientists to emigrate to the United States (where they played an important role in wartime science projects). During the war many European research facilities were damaged or destroyed, and afterwards the state of the European economies and the need for postwar reconstruction precluded a heavy emphasis on scientific research. In contrast, American research facilities were untouched by the war, and the scientific enterprise benefited from a booming postwar economy.

But it was the growth in federal funding, more than anything else, that vaulted the United States into a position of undisputed world leadership in science after the war.

Even before the United States entered World War II, the federal government moved to establish an agency to finance war-related scientific research. Scientists had worked on projects for the federal government during World War I, but they were placed under the direction of military supervisors and were subject to the constraints and restrictions that such supervision implies. This experience had been an

unhappy one, and scientists mobilizing for duty during World War II were determined to avoid its repetition.

Vannevar Bush, president of the Carnegie Institution of Washington, and chairman of NACA, led the scientists in organizing the war effort. A distinguished scientist at M.I.T. before becoming an administrator of science, he was convinced both that scientists would play an essential role in the war effort, and that they must not be dominated by the military.

Bush enlisted the aid of a number of influential scientists, and then persuaded President Roosevelt to issue, in June of 1940, an executive order creating the National Defense Research Committee (NDRC) with Bush himself as chairman. A year later, NDRC, along with the Committee on Medical Research, was further reorganized into the Office of Scientific Research and Development (OSRD).

OSRD was a predominantly civilian organization, cooperating with the military but reporting directly to the President. Under Bush, OSRD contracted to university laboratories for work on war-related research projects, including intitial development of the atomic bomb of the Los Alamos Scientific Laboratory, an adjunct to the University of California (the actual development of the bomb was funded separately, under the Manhattan District); radar at the M.I.T. Radiation Laboratory, the self-detonating proximity fuse at what is now the Applied Physics Laboratory at Johns Hopkins; and a number of smaller projects. OSRD obligated $536 million beween 1940 and 1946, of which roughly $300 million was in contracts to colleges and universities.

The research projects sponsored by OSRD were enormously successful in developing weapons and other military devices for the war effort.

The story of the Manhattan Engineering District, which developed the atomic bomb on the basis of work done on OSRD contracts, is well known; OSRD-sponsored work on radar and other projects contributed at least as much to the war effort. Bush and his colleagues managed to leave control over the conduct of research largely in the hands of the scientists. The contract used by OSRD did not dictate the precise goals of research or the methods to be used; it required only that the contractor "supply the necessary personnel and facilities for and conduct studies and experimental investigations in connection with" a given project.

The scientists emerged from the war convinced that their contributions had been indispensable to the war effort, and were the consequence of leaving the management of their efforts to the scientists. Congress and the public were equally convinced that generous and unconstrained support of science had worked wonders, and there was general agreement that this support should continue after the war. As the war drew to an end and work at OSRD laboratories wound down, attention focused on the form that this support would take.

Bush began to consider this question in 1944. He had intended from the beginning that OSRD would be phased out soon after the end of the war (OSRD was officially terminated on December 31, 1947). Consequently, Bush appointed a Committee on Postwar Policy which was directed to develop a plan for the postwar support of science.

Meanwhile, in the Congress, Senator Harley M. Kilgore, chairman of the Subcommittee on War Mobilization of the Committee on Military Affairs, proposed the creation of a new federal agency which would assume responsibility for all federal research support after the war. The agency would be headed by a presidentially-appointed director and guided by an

advisory board consisting of eight non-federal scientists and nine government officials. Its jurisdiction would be so broad as to encompass all basic research, applied research, and development, and even such programs as federal assistnace to small businesses.

The Kilgore proposal appalled Bush and his associates. They were convinced that science must be governed by scientists and not by presidential appointees and government officials; that control over federal research funds must be diffused rather than concentrated in the hands of a single agency administrator; and that basic science must be assured a special and independent source of support. Bush arranged for the President to send him a letter which gave him authority to conduct a study of postwar federal research support. The ensuing report, entitled Science, the Endless Frontier, put forth Bush's plan for a National Research Foundation controlled by a board of nine Foundation members selected from outside the government by the President. The members would appoint their own chairman and also appoint the director of the Foundation, effectively screening it from Executive oversight. The main purpose of the Foundation would be to make grants-in-aid to educational and non-profit research institutions for the support of basic research in the natural sciences.

Senator Warren Magnuson of Washington introduced a bill embodying Bush's design, and in subsequent hearings scientists attempted to persuade congressional leaders that basic science was unique and therefore required special treatment. They suffered a setback when, following the use of atomic bombs against Japan, a great debate arose over the control of atomic weaponry. One result of this debate was a petition signed by several hundred eminent scientists which conceded that the Foundation ought to be politically accountable to the administration.

In 1946, a compromise bill sponsored by Kilgore and Magnuson passed in the Senate but failed in the House. In 1947, a second compromise bill, which would have established a National Science Foundation following closely on Bush's recommendations, was introduced by Senator H. Alexander Smith of New Jersey. The Smith bill passed in both chambers, but was quickly vetoed by President Truman who refused to "vest the determination of vital national policies, the expenditure of large public funds, and the administration of important government functions in a group of individuals who would be essentially private citizens."

The National Science Foundation was finally established in 1950 on terms that made it accountable to the Executive Branch (and with a $15 million ceiling on appropriations which was lifted in August 1953). NSF obligations for the conduct of R & D for the first six years of its existence are given below.

TABLE 8

Fiscal Year	NSF Obligations for the Conduct of R & D $ millions
1951	0.1
1952	0.9
1953	2.3
1954	4.6
1955	9.7
1956	16.0

Five years passed between Bush's proposal for a National Research Foundation and the establishment of the National Science Foundation, and another three or four years passed before the NSF was given a significant level of appropriations. Some OSRD research contracts had been transferred to the Army and Navy Departments towards the end of World War II and were continued there after the war. In addition, OSRD contracts relating to military use of atomic energy were transferred to the Atomic Energy Commission when it was established in 1946. And much of OSRD's medical research program, along with the National Cancer Institute, was incorporated into the National Institute of Health by the Public Health Service Act of 1944.

Nevertheless, the virtual closing down of OSRD in 1946 and the delay in setting up a National Science Foundation to succeed it threatened to create a substantial gap in federal research support. The armed forces, and especially the Office of Naval Research (ONR), stepped in to fill the vacuum.

In part because of an unrelated jurisdictional dispute within the Navy Department, ONR (under the direction of Alan T. Waterman, the first chief scientist of ONR, and later the first director of NSF), became the patron of basic academic research in the immediate postwar years. Generous funding for ONR was available, both from department surpluses due to cancelled procurement contracts and from other agencies, within and outside the Navy, which were willing to support academic science. Waterman spoke at scores of universities, offering support for basic science (primarily the mathematical and physical sciences) on flexible and unrestrictive terms, and many of the nation's most prestigious institutions accepted contracts. ONR awarded $22 million in research

contracts to colleges and universities and other non-profit institutions in fiscal year 1947, and $50 million in FY 1951. Close to half of ONR's budget was spent on basic research, much of it on theoretical work which could only in the very long run be applied to the mission of the Navy.

For four years, from 1946 to 1950, ONR operated almost entirely without supervision from the Navy Department, which was barely aware of its existence. In 1950, under pressure from President Truman's cuts in the defense budget, the Navy rediscovered ONR and exerted pressure to reduce ONR's budget and to restrict it to supporting only those research projects which directly contributed to the Navy's mission. The outbreak of the Korean War restored ONR's budget, but the increase in supervision and the pressure for mission-related research remained.

Despite a brief decline in federal support of academic research in the years immediately following World War II, by the early 1950s the level of funding exceeded the highest level during the war and was growing at an average rate of sixteen percent each year, with well over half of the funds coming from the Navy, Army, and Air Force. At the same time, scientists were called upon for assistance in formulating military strategy at a series of "summer studies" devoted to tactical and strategic problems. The wartime experience, and especially the remarkable success in developing the atomic bomb, had convinced the military of the wisdom of listening to scientists, and of generously supporting their research.

By the middle 1950s, the drive for increased federal support of science began to lose some of its momentum. In 1957, Defense Secretary Charles E. Wilson, who presided over what was still by far the largest source of academic research funds, announced a ten percent cut in

Defense Department support of basic research. While NIH, NSF, and AEC were still increasing their spending, the postwar enthusiasm for academic science showed signs of cooling.

Then, on October 4, 1957, the Soviet Union successfully orbited Sputnik, the first artificial satellite. The United States at that time had two rockets in the final stages of development: the Vanguard, designed to launch satellites for scientific purposes, and the Jupiter C, intended for military use. Still, Sputnik sent shock waves through the federal government and the general public. This was not only a coup for Soviet science, but also a sign that the Russians might be ahead of the United States in developing rockets capable of delivering nuclear warheads.

The announcement in November of 1957 that the Soviet Union had launched a live dog into space increased fears that the Russians were outdistancing the United States in scientific achievements. A Vanguard was hastily readied for launch, carrying a 3½ pound satellite (compared with the 184 pound Sputnik), and before the eyes of the nation, on December 6, 1957, it exploded on the launch pad.

The government responded to the Sputnik crisis with a crash program to increase the nation's capability for space flight in particular and for science and technology in general. President Eisenhower appointed James R. Killian, the president of M.I.T., as Special Assistant to the President for Science and Technology, and formed a President's Science Advisory Committee in the White House. NASA was established shortly thereafter, and received large appropriations for space science and research.

Over the next seven years, the annual growth in federal funding of academic research averaged nineteen percent. Total federal research funds to universities and university-administered FFRDCs jumped from $547 million in FY 1958 to more than $1.5 billion in FY 1964. Much of this growth was in space and defense-related work of NASA and the Department of Defense, but the effect of Sputnik on funding spilled over to other agencies, including those supporting projects on unrelated topics. Although the growth in funding slowed after FY 1964, the entire decade following Sputnik was one of explosive growth in the funding of academic science.

In the mid-1960s, after twenty-five years of rapid and virtually uninterrupted growth, the inflow of federal dollars for academic research began to slow. In 1938, the federal government spent a total of $50 million on scientific R & D, of which roughly $6 million went to universities and colleges. By fiscal year 1964, annual federal R & D expenditures had reached $12.5 billion, with more than $1.5 billion spent on research at universities, colleges, and university-administered FFRDCs. Most scientists had become accustomed to ever-increasing annual funding and tended to take it for granted, but a few of them realized that federal research funding could not continue to grow at this rate indefinitely, and they saw signs that the Congress was becoming increasingly concerned about the amounts of money being appropriated for scientific research.

With increasing sophistication and force, Congressmen began to ask why funds were being sought, where and by whom they would be spend, how they were to be accounted for, and what results could be expected from such expenditures. In short, the Congress began to scrutinize science,

and found it expensive. Many Congressmen also found it difficult to distinguish between technology on the one hand and pure science on the other, and adopted the view that the federal government should support more research that produced useful applications and less "research done for the sake of research." President Johnson shared this view and also was unsympathetic with the concentration of federal research funds in a small number of institutions.

From FY 1964 to FY 1968, federal expenditures on academic research (including FFRDCs), measured in constant dollars, increased at an annual rate of seven percent, compared with a real growth rate of fifteen percent between FY 1954 and FY 1964. The federal government's interest in supporting basic science was faltering.

A few years earlier, George Kistiakowsky, a chemist who had succeeded Killian as Science Advisor to President Eisenhower, had foreseen that basic science would soon have to justify itself on arguments other than faith. He had been instrumental in establishing a Committee on Science and Public Policy (COSPUP) at the National Academy of Sciences with a mandate to study and make recommendations on any matter involving science and public policy. Under Kistiakowsky's chairmanship, COSPUP undertook a series of surveys of the prospects and needs of major fields of science. The first report, entitled Ground-Based Astronomy: A Ten-Year Program, was published in 1964. It was followed by Chemistry: Opportunities and Needs (1965), Physics: Survey and Outlook (1966), and seven other reports, the last of which, on materials science, was published in 1974.

Each of the COSPUP surveys described the research undertaken in a particular field of science and the scientific advances and social

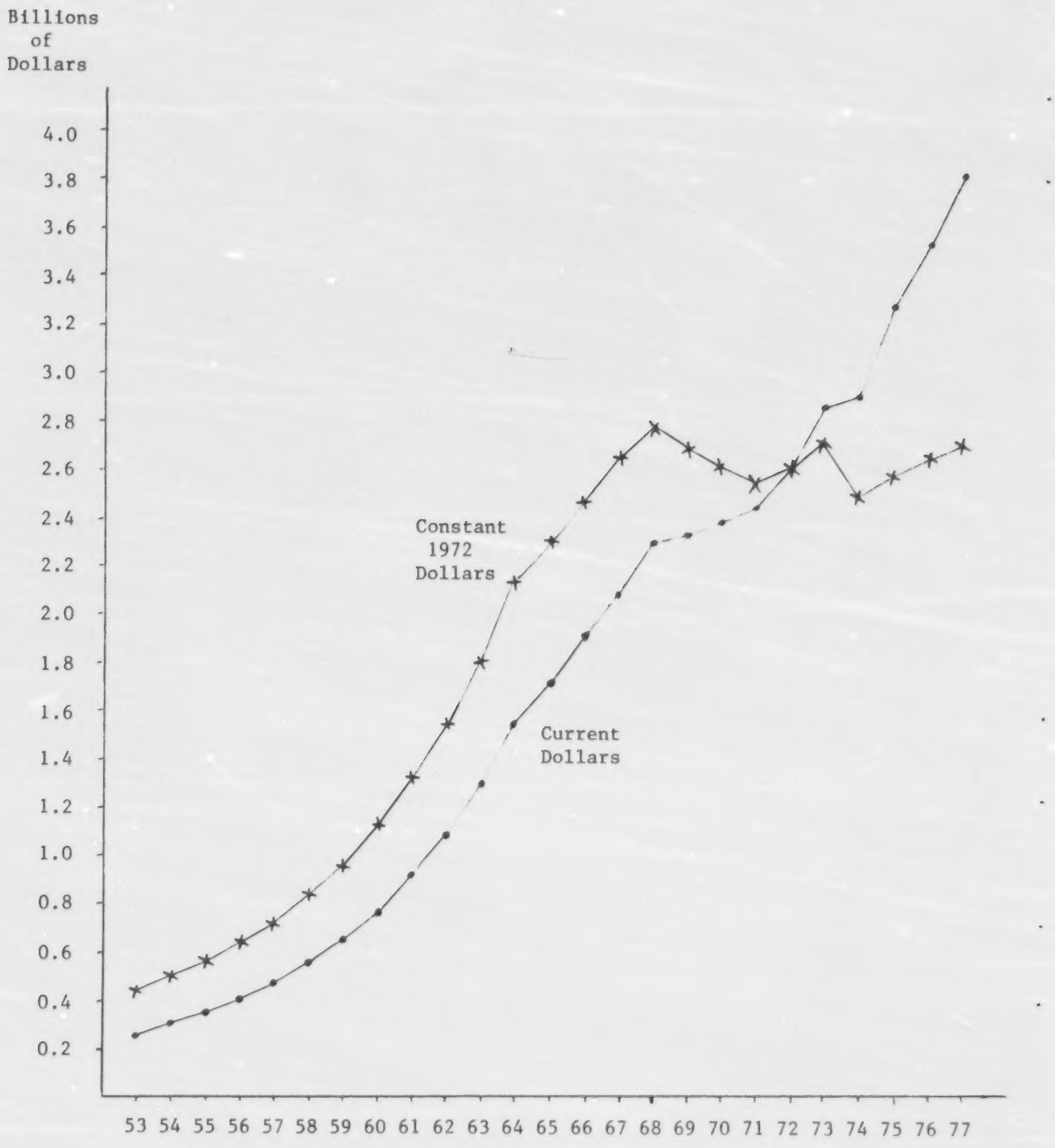
benefits that greater federal expenditures would produce. Taken as a whole, they represented a concerted effort on the part of the scientists to influence federal R & D policy and reverse the relative decline in research support, but they also revealed a certain amount of competition among scientists for the research funds that were now available in limited supply.

In previous years when each year brought substantially more federal funds than the last, it had not been necessary to make difficult choices between research projects or between fields of science; any competent scientist could obtain support for his research without depriving any other. By the mid-1960s, however, the federal funding was no longer growing as fast as research could absorb it, and more support for one scientist or for one field of science necessarily meant less support for another. Chemistry: Opportunities and Needs argued not only that chemistry needed more support but also that chemistry was receiving less than its fair share of the federal research budget, and this point was made with more or less force by several other COSPUP surveys.

Despite the scientists' efforts, the growth in federal funding of academic research came to an end in FY 1969. President Johnson, whose goal had been to finance the Vietnam war without sacrificing domestic programs, was forced to cut back domestic spending, including spending on research, in his last budgets. The Nixon administration held down the federal research spending in succeeding budgets as well. Federal funding of research at universities and FFRDCs measured in constant dollars (i.e., taking inflation into account) declined in fiscal years 1969, 1970, and 1971, increased slightly in 1972 and 1973, and declined in 1974. Despite modest increases in the 1975, 1976, 1977, and 1978 budgets, constant dollar federal support of academic research remains at present only slightly above FY 1968 levels.

FIGURE 1

Federally Funded Expenditures on Research and Development at Universities, Colleges, and University-Administered FFRDCs



The federal agencies that sponsored academic research in the early 1950s are, with few exceptions, the same agencies providing support today. Six agencies supplied ninety-nine percent of the funds in fiscal year 1954, and the same six agencies supply ninety-six percent of the funds today.

TABLE 9

Obligations of Principal Federal Agencies
for Research at Colleges and Universities
and at University-Administered FFRDCs,
FY 1954 and 1975
(dollars in millions)

Colleges and Universities	FY 1954	FY 1975
Total - All Agencies	140.9	2241.0
Agriculture	14.0	110.5
Defense	80.8	190.5
HEW	23.4	1189.4
AEC (ERDA)	16.4	119.1
NACA (NASA)	0.6	100.2
NSF	3.5	397.3
Total - Selected Agencies	138.7	2107.0
FFRDCs		
Total - All Agencies	130.2	1207.5
Defense	57.4	196.7
AEC (ERDA)	71.7	721.9
NACA (NASA)	--	227.5
NSF	--	57.6
Total - Selected Agencies	129.1	1203.7

The National Aeronautics and Space Administration (NASA), established in 1958, was an outgrowth of NACA, from which it received the nucleus of its staff and laboratories. The Energy Research and Development Administration (ERDA), established early in 1975 (and reorganized in 1977 as the Office of Energy Research in the Department of Energy), replaced the Atomic Energy Commission in supporting non-military nuclear research at universities and colleges and at ten university-administered Federally-Funded Research and Development Centers (FFRDCs). While these changes were something more than simple reorganization schemes, only one major source of federal academic research support - the Environmental Protection Agency - has appeared in the last twenty-five years. (EPA obligated $34 million for academic research in FY 1975.)

The major change that did take place during this period was the rapid growth in funding levels that we discussed above. As the preceding table shows, this growth was shared by all of the major funding agencies, but it was not shared equally.

In the first ten years after World War II, one agency - the Department of Defense - was the source of more than half of all federal support to on-campus academic research. If FFRDCs are included, two agencies - DOD and the Atomic Energy Commission - provided more than three-fourths of federal support.

In the decade after Sputnik, another agency - the National Institutes of Health within HEW - experienced tremendous growth. Today, NIH is the largest source of federally-sponsored academic research, providing more than half of all federal dollars for on-campus research. Virtually every university and college receiving federal research funds receives more dollars from NIH than from any other agency.

With the rise of NIH, the principal focus of academic research has shifted from the physical sciences and engineering to the life sciences. The next table illustrates this trend.

TABLE 10

Federally-Financed Expenditures for On-Campus Academic Research, by Broad Field of Science (dollars in millions)

	FY 1954	FY 1964	FY 1975
Physical and Mathematical Sciences	48	253	350
Engineering	52	125	260
Life Sciences	34	443	1238
Other Sciences	9	73	438

Federal support for on-campus academic research in the life sciences increased from twenty-four percent of the total in fiscal year 1954, to fifty percent in FY 1964, to fifty-four percent in FY 1975. In the same years, expenditures on research in the physical sciences and engineering declined from seventy percent of the total in FY 1954, to forty-two percent in FY 1964, to twenty-seven percent in FY 1975. (However, this trend did not extend to the university-administered FFRDCs, where in FY 1975, the physical sciences and engineering still accounted for eighty-nine percent of all research, and the life sciences for only four percent.)

What explains the dramatic growth of NIH funding in the late 1950s and 1960s? Part of the explanation is that NIH shared in the general post-Sputnik science boom. Still, from FY 1954 to FY 1967, while the obligations of all other agencies for academic research (including research at FFRDCs) were growing an average of thirteen percent annually, NIH obligations for academic research increased by about twenty-four percent annually (the figures given are for constant dollars). The explanation lies in the extraordinary success of a coalition of actors in lobbying for Congressional support for biomedical research.

The National Institutes of Health was created by the Ransdell Act of 1930, which directed that funds be appropriated for "study, investigation, and research in the fundamental problems of the diseases of man." Inherent in this wording is a basic ambiguity which reflected two conflicting views of the purpose of NIH. The scientists whose work was sponsored by NIH (including a large body of in-house staff scientists whose intramural research now accounts for almost one-fifth of NIH research funds) were interested primarily in advancing the state of scientific understanding. For them, the most important part of NIH's mandate were the words "research in fundamental problems," which suggested to them an emphasis on basic research in the biological sciences. In contrast, the Congressional supporters of NIH, together with a group of lobbyists who have been influential in promoting federal health expenditures, were interested primarily in the eradication of disease. They emphasized the "diseases" part of the mandate, and believed that NIH should support applied research on the prevention and cure of disease.

Lewis R. Thompson, the first director of NIH, recognized the importance of gaining the support of the latter group. Thompson was

responsible for the strategy which dominated, and still dominates, the relations between NIH and the Congress. NIH would consist of semi-autonomous research institutes. To gain wide support from the Congress and the public, each of the institutes would be linked to a specific set of diseases, and the implicit objective of that institute would be to eradicate that set of diseases. (The first such institute was the National Cancer Institute, established in 1937; there are now eleven National Institutes within NIH.) However, the principal means to this objective would be the support of investigator-initiated research projects, both intramural and extramural, including a substantial amount of basic research which, by definition, was directed at increasing scientific knowledge rather than curing disease. By preserving the ambiguity of purpose mentioned above, Thompson and his successors created an atmosphere in which Congressional and public interest in improving health would be translated into generous funding of basic research in the life sciences.

NIH survived an effort, immediately after World War II, to place biomedical research within the new National Science Foundation. The delay in creating NSF allowed NIH to take over unexpired wartime biomedical research contracts entered into by OSRD, preserving NIH as a base for biomedical research independent of the national research policy advocated by Vannevar Bush. Biomedical research had come through the war years with a reputation for excellence, largely on the basis of highly-publicized and successful work on the storage of blood plasma and the mass production of penicillin. Five new institutes were established in the late 1940s and early 1950s, as NIH appropriations began their dramatic increase.

This growth in NIH appropriations was largely the work of a coalition that was known as the "triple alliance." One key actor was James A. Shannon, a respected and able scientist/administrator who was the director of NIH from 1955 to 1968. The second element in the alliance was a private health lobby created by Mrs. Mary Lasker and Mrs. Daniel Mahoney. Mrs. Lasker virtually controlled the American Society for the Control of Cancer (predecessor of the American Cancer Society); Mrs. Mahoney was related by marriage to the owners of the Cox newspaper chain. They were both persuasive, influential, and indefatigable lobbyists. The third element of the alliance were champions of health in the Congress: Senators Lister Hill and Styles Bridges, and Representative John E. Fogarty.

Underlying this coalition was the ambiguity of purpose mentioned above: those who performed NIH-sponsored research were less interested in the eradication of disease and more interested in basic scientific theory than those who obtained the funding for it. Nevertheless, Dr. Shannon was successful in holding together the triple alliance through the middle 1960s, with the result that NIH received essentially open-ended authorizations during this period.

NIH benefited from the absence of any competing claims for health dollars; supporting NIH was virtually the only way for the Congress to commit resources to improving health. In the middle 1960s, Medicare, Medicaid, and a growing federal involvement in the provision of health care began to undermine NIH's Congressional support. NIH also came under attack from Senator William Proxmire and from Representative Lawrence H. Fountain, Chairman of the House Intergovernmental Relations Subcommittee. In a series of investigations, the Fountain Committee

criticized the management of NIH, the agency's policy of concentrating research grants in a small number of universities and medical schools, and the quality of the scientists supported and the research they undertook. And finally, the triple alliance, which had been so effective in increasing NIH appropriations, unraveled in the late 1960s, first with the death of Representative Fogarty in 1967, followed a year later by Dr. Shannon's retirement and Senator Hill's decision not to run for re-election. NIH appropriations (measured in constant dollars) held steady or declined in fiscal years 1968, 1969, 1970, and 1971, along with the budgets of other agencies funding academic science. In this four-year period, NIH appropriations (again measured in constant dollars) declined by five percent.

During this same period, however, public and Congressional support was developing for a major effort to cure cancer -- an effort which would restore growth to NIH appropriations.

A number of scientists had reservations about an all-out program to cure cancer. They argued that the war on cancer was politically motivated; that the fundamental scientific understanding which was a prerequisite to constructive work on a cancer cure was lacking; and that the proposed cancer program, by unduly emphasizing applied research, would curtail rather than support necessary basic research.

Despite these misgivings, the Cancer Act of 1971 passed overwhelmingly in the Congress, and was signed into law on December 23, 1971. The Act authorized expenditures of $1.5 billion for cancer research over a three-year period, and established a National Cancer Board with broad powers to formulate a national policy for cancer research. The cancer program remained within NIH but was given partial autonomy, with a

provision that the director of the National Cancer Institute be appointed directly by the President.

More than $4 billion has been spent on the war on cancer since passage of the Cancer Act of 1971. One result has been that support of academic research at NIH has not been affected nearly as much as at other agencies by the slowdown in federal R & D spending in the 1970s. Between FY 1971 and FY 1976, while the combined obligations of all other agencies declined by ten percent, NIH obligations for academic research increased by twenty-five percent. (The figures given are in constant dollars.)

At the same time, the heavy emphasis on cancer has meant that there is much more money available from NIH for cancer-related research than for work in other areas, which has led to the criticism that much worthwhile research is being undersupported for essentially political reasons. Many researchers also believe that the war on cancer was declared prematurely and that much more basic research is required first, to gain the fundamental understanding of biological processes that would provide the foundation for developing a cure. In a related vein, the cancer program has received some criticism for supporting second-rate work, although it is generally agreed that most of the research funded by NIH (including the intramural research at NIH, which amounted to $330 million in FY 1975), is of the highest quality.

APPENDIX B

MECHANISMS OF SUPPORT

A variety of mechanisms are available for supporting academic science. A federal agency could give lump-sum grants for the performance of research, either to a university or to a department within a university. It could award research fellowships to senior faculty, to junior faculty, or to doctoral or postdoctoral students. It could fund research centers or institutes staffed by university researchers. Or it could fund individual research projects at a university.

All of these mechanisms are in fact used by various agencies which support academic research, but the predominant means of support is the grant or contract in support of a specific research project undertaken by an individual investigator or by a group of investigators.

This pattern was set by OSRD, during World War II. The problem faced by the administrators of OSRD was to devise a mechanism of support which, while ensuring that government funds were properly used, would leave the scientist as much freedom as possible to proceed with his research unhindered by government regulations or outside supervision.

The mechanism which they chose was a short, standardized research contract between OSRD and the university at which the research project was to take place. The contract required only that the contractor "supply the necessary personnel for and conduct studies and experimental investigations in connection with" a specified research topic, leaving the scope and method of research entirely up to the investigator.

OSRD also decided to pay for the full costs of research performed, including overhead costs as well as costs that could be directly attributed to the research project.

Since World War II, the research grant-in-aid has largely superseded the research contract. Although research grants and contracts have different legal foundations and rely on different bodies of government regulations, there is little difference between them in practice, and they are used interchangeably by some agencies.

At present, most agencies which support research at universities rely largely on project grants or contracts as the principal mechanism of support. One major exception is the Department of Agriculture, which uses formula lump-sum grants to universities and colleges. In recent years, however, the Department of Agriculture has been rethinking its academic research program, and a new program of competitive project grants, begun in fiscal year 1978, is expected to grow in size and importance.

The Federally Funded Research and Development Centers, which are frequently regarded as performers of academic research, also fall outside the project grant/contract pattern. If FFRDCs are included as academic research, almost five-sixths of DOE's academic research budget, two-thirds of NASA's, and just over half of DOD's is spent at FFRDCs, while NSF and NIH each spend a small percentage of their budgets there. This mode of support was discussed above, and is excluded from the discussion here.

NIH and NSF, which together account for almost two-thirds of all federal support of academic research, both make extensive use of project grants, while also awarding a small number of project contracts. Project

grants or contracts are also used extensively by the Department of Defense (in all three service branches), the Department of Energy, NASA, and EPA.

The contemporary project grant is a direct descendant of the OSRD contract, with three principal changes. First, in the thirty years since OSRD, the body of regulations associated with research grants has grown considerably. Second, virtually all agencies now use some form of peer review in deciding which research projects to support. And third, universities are now required to share in the cost of federally-sponsored research, by foregoing some portion of reimbursement for the costs of research projects.

The Project Grant

Research Proposals: Research proposals are typically initiated by an individual investigator, who seeks funding for a specific experiment or project which he wishes to perform. (The majority of research projects are undertaken by a single senior investigator, assisted by a small number of postdoctoral fellows, graduate students, and laboratory assistants, and perhaps by a junior faculty member. Some larger projects involve two or more investigators on an equal basis, one of whom is usually named the principal investigator for the purposes of the grant.) In a few cases, NIH and NSF solicit proposals for work on pre-set topics. In practice, the distinction is not an important one, since there is a fair amount of communication between university researchers and agency program officers, and the former are usually aware of what types of projects the agency is likely to support.

The proposal, which must conform to a rigidly specified format, includes three types of information. First, the investigator gives a detailed description of the proposed work, reviewing previous work in the same field, and defending the objectives, scientific significance, and methods of the project. Second, the investigator presents evidence of his ability to carry out the research successfully, including his own credentials and those of this colleagues, and the suitability of the facilities at his university. And third, he presents a detailed budget for the first year of research, covering all salaries and fringe benefits, equipment, materials, and supplies, travel and publication costs, computer costs, and overhead costs.

A researcher seeking support for a project must spend a substantial amount of time preparing his proposal, especially if he feels that he must submit proposals to several agencies in order to have a fair chance of receiving support. The criticism is often made that if proposals were less detailed, this time could be put to more constructive use. However, a researcher typically submits new proposals only every two or three years, and the process of writing the detailed description of the proposed research, which will be scrutinized closely in the process of peer review, may have a positive effect on the quality of the proposal.

Peer Review: Except in cases where the amount of money involved is quite large, the decision to fund a particular research project is made by a program officer at the funding agency. At some agencies, the program officers are themselves academic scientists, who work for the agency for a relatively short period of time and then return to the university. At others, they are typically civil service scientists, with little direct experience in research. And at still other agencies, the program officers are professional bureaucrats, with no first-hand experience in

the fields of science in which they award research grants or contracts. Not surprisingly, the reputations of the various agencies, in terms of the quality of research projects that they support, vary considerably.

Rather than relying entirely on the judgment of the program officer, NIH and NSF submit all research proposals to a process of review by active civilian researchers qualified to judge the scientific merits of the proposed research. DOE, NASA, and the Department of Defense use peer review for a portion of their awards.

At NIH, a research proposal is first assigned to the appropriate Institute (or Institutes), and is then forwarded to one of several standing panels, known as NIH "study sections." Each study section, which consists of a dozen or so active researchers (mostly academic scientists), meets three times a year, having read the backlog of proposals in advance, to discuss the various proposals and rank them in order of scientific merit. The ranked list is then given to the program officer at the relevant Institute. In practice, the program officer exercises very little discretion in the selection of research projects; he essentially starts at the top of the list and funds projects until his budget is exhausted. An exception is the National Cancer Institute, where program officers exercise more discretion, using programmatic as well as scientific criteria to select projects.

NSF uses this style of "panel review" at times, but usually employs a process of "ad hoc review," which gives the program officer more discretion in the funding of projects. The Foundation maintains a list of approximately 30,000 civilian researchers (again, mostly academic scientists); each proposal is sent to from three to ten reviewers from the list who are knowledgeable in the field represented by the proposal.

The program officer decides which projects to fund, based on his own judgment and on the recommendations of the reviewers. His decisions are then reviewed within NSF prior to the actual awarding of grants.

Peer review periodically comes under attack in the Congress, usually on the basis of complaints that the process is systematically biased in favor of proposals from the more prestigious universities, or from more established or more senior researchers, or from researchers who have in the past received research grants. Given the fact that the reviewers tend to be eminent researchers, and therefore mostly senior faculty members of prestigious universities, it would not be surprising to find such an "old boys' network" at work. However, this appears not to be the case.

In 1976, the National Academy of Sciences published a study of the fairness of peer review at NSF. The study, based on a statistical analysis of 1200 funding decisions during 1975, concluded that these biases were not present:

> ...we can definitely conclude that <u>there is no evidence</u> that eminent investigators from prestigious institutions who have an established track record, and who have been around for a long time, have a considerably better chance of receiving favorable ratings on their proposals than noneminent investigators at less prestigious institutions without any track record and who have not been around for a long time. We must presume that the great bulk of variance on these ratings is either a result of the perception of the quality of the proposal or else of a random grading process.

Notwithstanding this finding, several reforms in the peer review process have emerged from the latest round of Congressional investigation. NSF has adopted a formal appeals procedure on an experimental basis, a move which NIH is now considering. NSF has also begun publishing a list of all active ad hoc reviewers, and has adopted a policy of sending

verbatim copies of peer reviewers's comments (with the reviewers's names deleted) to principal investigators who request them. Finally, the Congress has asked NSF to consider deleting the names of principal investigators and their institutions from proposals before submitting them to peer review -- a questionable policy which would make effective review extremely difficult.

Peer review has been criticized on two other grounds. First, the review process contributes to the long delay between submittal and disposition of a research proposal, a delay which typically runs from six to nine months. And second, the process places a large burden on the reviewers, especially those who serve on peer review panels, who must spend a significant amount of time, that they could otherwise devote to research and teaching, on the review process.

Some reviewers have commented, however, that the time spent in reading research proposals has helped them to stay in touch with new developments in thier fields. And some researchers who have received site visits as part of the peer review of larger grants have used the comments of the visiting reviewers to improve their research projects.

On balance, it is the opinion of most members of the scientific community that the peer review process is the best method yet devised for choosing between competing research proposals. Section III of this paper argued the importance of judging research projects solely on the basis of scientific excellence. The peer review system is designed to do precisely that, and it does it with an appearance of objectivity and neutrality which gives it considerable immunity to political attack. At the same time, it blunts the decision-making power of agency program officers, and prevents them from exercising an undesirable degree of control over the direction of research.

Project Grant and Contract Awards: If a research proposal is favorably reviewed and is judged by the program officer to merit support, and if funds are available in the agency's budget, an award is made to the university at which the research is to take place, on behalf of the principal investigator, typically for a period of one to five years. If a grant runs more than one year, it must be renewed annually, but the investigator is only required to submit a brief progress report, a report of expenditures in the preceding year, and a budget for the following year. The renewal is not subject to peer review, and is usually automatic.

However, an investigator who desires support for a longer period of time (and this is typically the case) must submit a new proposal when his grant runs out, and this "renewal" is considered in competition with all other proposals pending at that time. In practice, the funding agency tries to assure continuity of support to researchers whose work is productive, but an investigator who undertakes a long-term project cannot avoid the risk that his funds will be cut off abruptly before his work is completed.

In recent years, as federal research funds (measured in constant dollars) have declined, the average grant award has shrunk, at some agencies in duration and at others in dollars per year. At the same time, the ratio of successful proposals to total proposals has fallen, and the award of "grants without funding" has become a fairly common practice. This has had two effects on the peer review system. First, researchers have been forced to submit proposals for a single research project to several agencies, in the hope of finding one willing to support the project, or several willing to give partial support. The

result has been a dramatic increase in the burdens of proposal preparation by the investigator, and of proposal processing by the agencies by peer reviewers. And second, the falling success ratio has increased dissatisfaction with the peer review system on the part of unsuccessful applicants.

Reporting and Record-Keeping Requirements: Recipients of research grants and contracts are required to comply with requirements relating to changes in the direction of research, progress reporting, and financial record-keeping.

Most agencies have only minimal requirements for the reporting of the scientific progress in a research project. Both NSF and NIH require annual progress reports from all multi-year grants, but these reports can be very brief. Even in the case of final reports, a copy of the journal article presenting the outcome of the research project will usually suffice. One occasionally hears criticism of the burden placed on investigators by agency-mandated progress reporting, but for most agencies this burden is in fact modest.

NSF, NIH, and most other federal agencies which support academic research have stayed fairly close to the position that OSRD took with regard to the need to report changes in the direction of an ongoing research project to the funding agency. NSF has been particularly liberal. Its policy has been that:

> The principal investigator may discontinue or materially modify unpromising lines of inquiry, without jeopardizing continuation of support...when it appears from a scientific standpoint that the inquiry as originally envisaged will no longer be fruitful or that a related line of inquiry will be more promising. However, prior approval by the Foundation must be obtained when such modification would result in a major deviation from original research objectives....

NIH has a similar policy, allowing "minor changes." However, since "minor" and "major" are not clearly defined by NIH, researchers have been somewhat more reluctant to modify the direction of NIH-sponsored research in order to following interesting leads, since this might jeopardize support.

Investigators feel that NSF, NIH, and most other agencies have tightened control over the direction of research in recent years, both by requiring that the methods of research be spelled out in greater detail in the research proposal, and by insisting more often that prior approval be obtained for modifications in the line of research. Since this approval procedure can take a month or more, the latter requirement can significantly delay the progress of the research project.

While NSF gives the investigator considerable latitude in deciding on the direction of research, it requires that any transfer of funds between cost categories listed in the research budget - for example, a decision to spend less on materials and supplies and more on computer processing - be submitted for prior approval. NIH follows the Public Health Service policy of permitting the investigator to rebudget the direct costs of research as he sees fit, as long as he stays within the total direct cost budget of the project. Neither agency permits re-budgeting of indirect costs.

Each agency has an extensive body of regulations governing the acquisition and management of equipment, with minor variations from agency to agency. Briefly, an investigator is required to obtain prior approval for the purchase of any item of equipment costing more than a certain amount (typically $1,000); and he must maintain records of the acquisition, use, and ultimate disposition of equipment and other

property purchased under a grant. Similar requirements apply to research funds spent on travel.

Just as investigators are required to keep records of expenditures on equipment and supplies in order to document the proper and full use of the project's budget funds, they are also required to keep monthly records of the time that all project personnel spend on the research project. This "time and effort reporting" is strongly criticized by many academic researchers, who feel that a "time clock" is particularly inappropriate for scientists and scholars.

A research project can avoid time and effort reporting for the project's professional staff by negotiating stipulated salaries for them during the preparation of the research proposal. However, most universities choose to reject this alternative, either for internal administrative reasons, or because of uncertainties at the time of proposal preparation as to the extent of participation by particular investigators. For those universities which reject stipulated salaries, time and effort reporting is a large source of faculty dissatisfaction with federal grant administration.

Indirect Costs: The total cost of a research project includes both those costs that can be directly attributed to it, and some share of the overhead costs of the university. The former are usually referred to as the direct costs, and the latter as the indirect or overhead costs of research.

The direct costs of research at a university can easily be computed and assigned to individual research projects. However, indirect costs help pay for services and facilities which are shared by more than one research project, or by research projects and other university functions.

Consequently, extensive accounting procedures are needed to determine a particular research project's indirect costs.

The distinction between direct and indirect costs can be illustrated by a few examples. The salary of an investigator who works full time on a research project (or half the salary of an investigator who works half-time) is a direct cost. So is the cost of materials and supplies consumed in the project. However, the cost of heating the laboratory in which the project takes place is an indirect cost, since it is inseparable from the cost of heating the entire building, which also houses classrooms and other research projects. So is depreciation of the building, and the cost of maintaining it. If the project is an experiment in chemistry, then some part of the chemistry department chairman's salary and of the salaries of the department staff are indirect costs, since they spend some portion of their time administering the project. And some portion of the expense of running the university's personnel, accounting, and payroll offices are indirect costs, since these offices have administrative tasks relating to the project.

All of these are costs that the university would bear even if this particular project was not undertaken. However, the research project is consuming university resources that would otherwise be available for other uses. Indirect costs are not simply a form of institutional support that accompanies research grants; they are genuine costs of performing a research project. The federal government recognizes this, and reimburses universities for the indirect costs of federally-funded research.

The procedures for computing the indirect costs of individual research grants and contracts are governed by Federal Management

Circular 73-8, issued by the General Services Administration (previously issued by the Bureau of the Budget, and later by OMB, as Circular A-21). FMC 73-8 instructs each university which receives federal research contracts or grants to compute an overall indirect cost rate equal to the average ratio of indirect to direct costs for all separately budgeted research conducted at that university, regardless of funding source. The indirect cost rate can be summarized as:

$$\text{Indirect Cost Rate} = \frac{\text{Total Allowable Indirect Costs of Research}}{\text{Total (selected) Direct Costs of Research}}$$

The indirect cost rate is then applied to each research project supported by a federal grant or contract, to determine the amount of indirect cost reimbursement which the project will receive. The university can choose from four methods for negotiating the indirect cost rate. The first option is to negotiate a provisional rate at the beginning of the fiscal year, which is applied to research projects during the year. At the end of the year a final negotiation fixes the actual rate, and a retroactive adjustment is made. The problem with this method is that by the end of the fiscal year the funding agency has usually spent all its funds, so that retroactive payments to the university are rarely made. The second option is to negotiate a fixed rate in advance, usually for a period of one or more years, if both parties agree that it will be equitable. The fixed rate is usually the same as the last negotiated rate. The third option, which is the most popular, is to negotiate a fixed rate, but also to roll-forward any over- or under-reimbursement from a previous year as an adjustment to the next year's negotiated rate. Finally, the university can negotiate a separate lump-sum indirect cost reimbursement instead of a rate for off-campus projects and other

projects or laboratories which are fairly distinct from the campus. This method is generally confined to FFRDCs.

Several points relating to indirect costs merit some discussion. First, the distinction between direct and indirect costs is flexible, since a university can sometimes convert one into the other by changing either of its operating practices. For example, by assigning departmental secretaries to individual research projects, the university can remove their salaries from the "departmental administration" indirect cost pool and assign them as direct costs of the projects. Or, the cost of electricity consumed by research projects, which is usually treated as an indirect cost, can be converted to a direct cost by installing individual electrical meters at each research site. The result would be a decrease in the indirect cost rate, and an offsetting increase in the amount of direct costs. Conversely, increased sharing of equipment among research projects converts direct into indirect costs. Thus, differences in operating practices also contribute to the variance in indirect cost rates among universities.

Indirect cost rates have been increasing steadily over the past few years. For example, between 1966 and 1976, the indirect costs of NSF basic research project grants increased from sixteen to twenty-five percent of total project costs. Some of this increase is attributable to inflation, which bears more heavily on indirect than on direct costs; in particular, increases in the price of energy fall almost entirely on the indirect cost portion of research budgets. In addition, the cost of complying with new federally-mandated social programs, such as affirmative action, has increased the costs of administration, which is an indirect cost; and federal occupational safety and health standards

and standards for the care of laboratory animals have increased operation and maintenance budgets.

This trend of rising indirect costs has aroused concern in the Congress, since a higher indirect cost rate means that the same expenditure of funds buys less research. There has been some discussion of establishing ceilings on indirect cost rates. FMC 73-8 is now being revised, partly in response to pressure from OMB and from the House Appropriations Committee to hold down indirect costs.

The high administrative cost of the current scheme, both for the universities that compute indirect cost rates and for the agencies that audit and approve them, has prompted some discussion of a uniform indirect cost rate. OSRD used a uniform rate of fifty percent of wages and salaries for some if its smaller contracts, and the savings involved in adopting such a standardized procedure are quite attractive.

Both the uniform indirect cost rate, and the rate ceiling (which would probably be implemented as a uniform rate) suffer from three shortcomings. First, they would probably make it necessary for all universities to adopt a standardized accounting system prescribed by the federal government, and no single accounting system is likely to be acceptable to the wide variety of universities receiving federal research support. Second, because there are genuine differences in indirect cost rates from one univeristy to another, a uniform rate will not be as equitable as the current scheme: it is likely to over-reimburse or under-reimburse some institutions. And third, a uniform rate will create an incentive for universities to change their operating procedures in order to convert indirect into direct costs - sometimes in ways that increase their overall costs - thereby increasing their total cost recovery, and defeating the purpose of a rate ceiling.

This last point suggests that preoccupation with increases in the indirect cost rate as such may be misguided. What is of concern is the rising costs of research, and whether these costs happen to be direct or indirect is of secondary importance.

FMC 73-8 states that it is "designed to provide recognition of the full allocated costs of such research work under generally accepted accounting principles." Nevertheless, since 1966, HEW has required universities to share in the cost of its research grants, and cost-sharing is now an almost universal feature of academic research. The cost-sharing usually takes the form of less than full reimbursement of indirect costs. Often the government will simply fail to pay the university the full amount that had been agreed upon in the indirect cost negotiation.

As was discussed in section III of this paper, cost-sharing is widely regarded as unjustified by university administrators, who feel that the government should pay the full cost of sponsored research. Cost-sharing also creates a certain amount of friction between departments, based on the perception that federally-funded research draws university dollars away from other university activities to cover unreimbursed indirect costs.

The arrangements for indirect cost recovery have been the source of a different type of friction as well. The university researcher, who sees a quarter of his budget siphoned off for university overhead, sometimes has a tendency to regard indirect costs as money down the drain. Similarly, the university administrator may look wistfully at the money that is spent on the research project and wish that more of it could be made available for running the university. These feelings

are not very pronounced, but it can be argued that the current arrangements for indirect cost recovery are not well-designed to promote cooperation between researchers and administrators.

In principle, the indirect costs associated with a research project are fixed by the amount of salaries and wages. In practice, however, given the combined interest of agency program officers and university investigators in maximizing the amount of a grant that is spent on the conduct of research, a certain amount of fudging of salaries in order to reduce indirect costs apparently takes place. The result is that the investigator can increase the amount of direct costs in the proposed budget and deliver more research for the same overall budget, thus making his proposal more attractive to peer reviewers and program officers. In this respect, there is a significant difference in the practices of NSF and NIH. NSF peer reviewers evaluate proposals on the basis of their total budget, including indirect costs, while NIH study sections are shown only the direct costs of a project, with the program officer adding indirect costs only after a project has been ranked. Thus, NIH grants may be more immune to this kind of "fudging" of indirect costs.

Finally, we note a peculiar interaction between federal support of academic research and state support of public universities. The spending authority of a state university is typically set by its state legislature. Revenues received by the state university, including tuition and miscellaneous sales and services, are applied towards the spending authority, and the university receives a general fund appropriation from the state to cover the balance. Direct cost recovery of federally-supported research is specifically excluded from this procedure, but in several

states indirect cost recovery is not. When a public university in one of these states accepts a federal research grant, the indirect cost reimbursement which it receives to pay for the grant's increment to overhead expenses is exactly offset by a decrease in the state's contribution to the university. In other states, public universities are allowed to keep some or all of the indirect cost reimbursement, despite the fact that it is meant to cover a portion of expenses, such as library operations, which are in theory entirely covered by the state's appropriation. In practice, such funds are usually regarded as discretionary by the university administration, and are rarely spent on research costs, direct or indirect.

ADDITIONAL STATISTICAL TABLES

TABLE 11

Federally-Financed Expenditures on Research and Development
at Universities, Colleges, and University-Administered FFRDCs

Calendar Year	CURRENT DOLLARS (Millions) Colleges and Univ.	FFRDC	Total	CONSTANT 1972 DOLLARS (Millions) Colleges and Univ.	FFRDC	Total
1953	138	121	259	234	205	439
1954	160	141	301	268	236	504
1955	169	180	349	277	295	572
1956	213	194	407	339	308	647
1957	229	240	469	352	369	721
1958	254	293	547	384	444	828
1959	306	338	644	453	501	954
1960	405	360	765	590	524	1,114
1961	500	410	910	722	592	1,314
1962	613	470	1,083	869	666	1,535
1963	760	530	1,290	1,062	740	1,802
1964	916	629	1,545	1,260	865	2,125
1965	1,073	629	1,702	1,444	846	2,290
1966	1,262	630	1,892	1,644	821	2,465
1967	1,409	673	2,082	1,783	852	2,635
1968	1,573	719	2,292	1,905	871	2,776
1969	1,595	725	2,320	1,839	836	2,675
1970	1,648	737	2,385	1,804	806	2,610
1971	1,724	716	2,440	1,795	746	2,541
1972	1,839	764	2,603	1,839	764	2,603
1973	2,038	817	2,855	1,926	772	2,698
1974	2,032	865	2,897	1,746	743	2,489
1975	2,285	987	3,272	1,795	776	2,572
1976 (est)	2,450	1,080	3,530	1,831	807	2,638
1977 (est)	2,634	1,177	3,811	1,864	833	2,697

TABLE 12

Federal Outlays for R & D and R & D Plant, All Performers

Selected Fiscal Years 1940-1975

	Federal R&D Outlays in Constant 1967 Dollars (Millions)	Federal R&D Outlays as a Percentage of Total Federal Budget Outlays	National R&D Outlays as a Percentage of GNP
1940	220	0.8%	0.4%
1945	3,700	1.7	N.A.
1950	1,880	2.5	N.A.
1955	5,420	4.8	1.5
1960	11,280	8.4	2.7
1965	20,030	12.6	2.9
1970	17,220	8.0	2.8
1975	15,400	6.0	2.3

TABLE 13

National expenditures for performance of R&D as a percent of Gross National Product (GNP) by country, 1961-76

Year	Canada	France	Germany	Japan	United Kingdom	United States	U.S.S.R.
R&D Expenditures As a Percent of Gross National Product							
1961	1.01	1.38	NA	NA	2.69	2.74	NA
1962	.95	1.43	1.25	1.48	NA	2.73	2.37
1963	.95	1.53	1.40	NA	NA	2.87	2.37
1964	1.05	1.78	1.56	NA	2.62	2.97	2.42
1965	1.17	1.99	1.72	1.55	NA	2.92	2.40
1966	1.21	2.07	1.80	1.50	2.68	2.91	2.42
1967	1.33	2.16	1.97	1.55	2.69	2.91	2.55
1968	1.33	2.12	1.95	1.51	2.65	2.84	NA
1969	1.34	1.96	2.02	1.71	2.63	2.75	2.62
1970	1.29	1.88	2.16	1.86	NA	2.65	2.79
1971	1.25	1.87	2.36	1.88	NA	2.50	2.85
1972	1.17	1.83	2.31	1.89	2.39	2.43	3.13
1973	1.11	1.73	2.22	1.92	NA	2.33	3.19
1974	1.09	NA	2.23	1.99	NA	2.29	3.13
1975	NA	1.48	2.25	NA	NA	2.32	3.18
1976	NA	NA	2.13	NA	NA	2.25	NA

TABLE 14

Enrollment for Advanced Degrees by Field, 1960-75

Fall Term	All Fields	Science and Engineering Fields						
		Total	Physical and environmental sciences	Engineering	Mathematical sciences	Life and agricultural sciences	Social sciences	All other fields
				Number				
1960	314,349	120,638	25,707	36,636	11,770	19,715	26,810	193,711
1961	338,981	128,794	26,553	39,367	12,671	21,446	28,757	210,187
1962	373,845	142,433	28,591	43,850	14,121	23,953	31,918	231,412
1963	413,366	158,051	30,959	48,917	15,974	26,888	35,313	255,315
1964	477,535	178,123	34,061	54,318	18,805	30,787	40,152	299,412
1965	535,332	195,346	36,506	57,516	21,014	34,749	45,561	339,986
1966	583,000	207,049	37,950	58,338	23,150	37,007	50,604	375,951
1967	649,697	224,468	40,477	62,633	25,066	39,954	56,368	425,229
1968	703,745	234,661	40,937	63,662	26,840	41,676	61,546	469,084
1969	756,865	243,715	39,885	65,048	29,175	44,203	65,404	513,150
1970	816,207	252,159	40,113	64,788	30,608	46,260	70,390	564,048
1971	836,294	246,100	38,928	59,321	28,847	47,662	71,342	590,194
1972	858,580	242,988	36,047	55,847	28,064	49,118	73,912	615,592
1973	908,101	244,354	35,995	54,567	27,023	50,714	76,055	663,747
1974	965,000	250,673	34,936	56,001	27,118	54,225	78,393	714,327
1975	1,053,769	261,522	35,497	59,304	27,024	58,049	81,648	792,247

TABLE 14 (continued)

Enrollment for Advanced Degrees by Field, 1960-75

Fall Term	All Fields	Science and Engineering Fields: Total	Physical and environmental sciences	Engineering	Mathematical sciences	Life and agricultural sciences	Social sciences	All other fields
		As a Percent of All Fields						
960	100	38	8	12	4	6	9	62
961	100	38	8	12	4	6	9	62
962	100	38	8	12	4	6	9	62
963	100	38	8	12	4	7	9	62
964	100	37	7	11	4	6	8	63
965	100	37	9	11	4	7	9	63
966	100	36	7	10	4	6	9	64
967	100	35	6	10	4	6	9	65
968	100	33	6	9	4	6	9	67
969	100	32	5	9	4	6	9	68
970	100	31	5	8	4	6	9	69
971	100	29	5	7	3	6	9	71
972	100	28	4	7	3	6	9	72
973	100	27	4	6	3	6	8	73
974	100	26	4	6	3	6	8	74
975	100	25	3	6	3	6	8	75

TABLE 15

Nobel Prize Laureates in Science for Selected Countries, 1901-1976

Period	United States	United Kingdom	West Germany	France	U.S.S.R.	Switzer-land	Nether-lands
1901-1910	1	5	12	6	2	1	4
1911-1920	2	3	7	4		2	1
1921-1930	3	7	8	3			2
1931-1940	9	7	9	2		2	1
1941-1950	14	7	4			3	
1951-1960	29	9	3		4		1
1961-1970	25	12	5	5	3		
1971-1976	22	8	3			1	
TOTAL:	105	58	51	20	9	9	9

TABLE 16

Federally Funded Research and Development Centers
Administered by Universities and Colleges

FFRDC	Federal Obligations FY 1975 ($ millions)	Principal Funding Agency	Administered By
Ames Laboratory	8	DOE	Iowa State University
Applied Physics Laboratory	90	DOD	Johns Hopkins University
Applied Research Laboratory	9	DOD	Pennsylvania State University
Argonne National Laboratory	136	DOE	University of Chicago and Argonne University Assoc.
Brookhaven National Laboratory	72	DOE	Associated Universities Inc.
Center for Naval Analyses	11	DOD	University of Rochester
Cerro Tololo Inter-American Observatory	3	NSF	Association of Universities for Research in Astronomy
Jet Propulsion Laboratory	227	NASA	California Institute of Technology
Kitt Peak National Observatory	9	NSF	Association of Universities for Research in Astronomy

TABLE 16 (continued)

FFRDC	Federal Obligations FY 1975 ($ millions)	Principal Funding Agency	Administered By
Lawrence Berkeley Laboratory	42	DOE	University of California
Lawrence Livermore Laboratory	173	DOE	University of California
Lincoln Laboratory	86	DOD	Massachusetts Institute of Technology
Los Alamos Scientific Laboratory	179	DOE	University of California
National Accelerator Laboratory (Fermilab)	57	DOE	University Research Associates
National Astronomy and Ionosphere Center	3	NSF	Cornell University
National Center for Atmospheric Research	22	NSF	University Corporation for Atmospheric Research
National Radio Astronomy Observatory	19	NSF	Associated Universities, Inc.
Oak Ridge Associated Universites	6	DOE	Oak Ridge Associated Universities
Plasma Physics Laboratory	23	DOE	Princeton University

TABLE 16 (continued)

FFRDC	Federal Obligations FY 1975 ($ millions)	Principal Funding Agency	Administered By
Stanford Linear Accelerator Center	31	DOE	Stanford University
Space Radiation Effects Laboratory	1	NSF,DOE	College of William and Mary

SOURCES

SOURCES

Much of the material in this paper was drawn from the following sources, which are commended to the reader as sources of additional information.

Sources	Topic
James R. Killian, Jr., Sputnik, Scientists, and Eisenhower	History of federal support to scientific research
Daniel Greenberg, The Politics of Pure Science	History of federal support to scientific research
National Academy of Sciences, Basic Research and National Goals	The object, level, and allocation of federal support to basic research
University of California Research Management Improvement Project, The Impact of Federal Regulations in Colleges and Universities: Overview and Summaries	Federal oversight and regulation of academic research
U.S. House of Representatives, 1978 National Science Foundation Authorization Hearings, extracts	Peer review
Joseph E. Cantor, Congressional Research Service, A Primer on Indirect Costs of Federal Research Grants and Contracts	Indirect Costs
Clifford Grobstein, "The Recombinant-DNA Debate," Scientific American, July 1977	Recombinant DNA
National Science Foundation/National Science Board statistical documents: - Science Indicators 1976 - National Patterns of R & D Resources, 1953-1977, especially tables B-1 through B-4 - Federal Support to Universities, Colleges, and Selected Non Profit Institutions, Fiscal Year 1975, Detailed Statistical Tables especially tables B-2, B-6, B-8, B-9, B-13, and B-33	Federal Expenditures on Academic Research

National Science Foundation/National Science Board statistical documents (continued):

- Expenditures for Scientific Activities at Universities and Colleges, Fiscal Year 1975, Detailed Statistical Tables especially tables B-7 and B-48

- Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1975, 1976, and 1977, Detailed Statistical Tables

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We also wish to draw the reader's attention to a number of government reports, and reports from the scientific community, which have been influential in shaping federal research policy.

1937 — National Resources Committee, Research, a National Resource. Called for an increase in federal funding of basic research.

1945 — Vannevar Bush, Science, the Endless Frontier. Urged greater funding of research, especially basic research. Proposed establishment of a National Research Foundation to "support basic research in non-profit organizations." Urged measures to develop science manpower. Also discussed issues specific to postwar scientific conversion.

1947 — The President's Scientific Research Board, Science and Public Policy ("Steelman Report"). Similar to the Bush report. Proposed a National Science Foundation.

1957 — National Science Foundation, Basic Research: A National Resource. Urged greater support to basic research, from federal and non-federal sources, for conduct of basic research and research facilities. Recommended less restrictions on the use of research funds and simplified administration of funds.

1958 National Science Foundation, Government-University Relationships in Federally Sponsored Research and Development. Recommended greater funding of academic research. Expressed concern over emphasis on targeted research. Recommended disassociating research support from general support to higher education. Advocated multiple sources of funding, simplified administration, less restrictions on the use of funds, continuity of funding. Advocated funding basic research at universities and colleges; applied research and development elsewhere.

1960 President's Science Advisory Committee, Scientific Progress, the Universities, and the Federal Government ("Seaborg Report"). Urged greater support to basic research, and to science manpower development. Argued that basic research is a necessary part of graduate education, and that the two activities belong together. Advocated flexible support mechanisms and less government interference in the conduct of research.

1962 Bureau of the Budget, Report to the President on Government Contracting for Research and Development ("Bell Report"). Discussed whether and how the federal government should contract for R & D. Advocated increased federal support for R & D performance and manpower.

1964-1974 COSPUP reports.
Advocated greater federal support to basic research in various disciplines.

1976 National Science Board, Science at the Bicentennial. Surveyed the research community on problems facing the long-term basic research effort. Discussed many of the issues treated in section II of this paper.

1976, 1977 Willis Shapley, American Association for the Advancement of Science, Research and Development in the Federal Budget: FY 1977, and FY 1978.
An annual analysis of R & D funding in the federal budget.

SOURCES OF TABLES

Tables 1, 2	NSF, National Patterns of R & D Resources, 1953-1977, table B-2
Table 3	NSF, Federal Support to Universities, Colleges, and Selected Nonprofit Institutions, FY 1976, Appendix B table B-1
Table 4	NSF, Expenditures for Scientific Activities at Universities and Colleges, FY 1975, Appendix B table B-1
Table 5	NSF, Expenditures for Scientific Activities at Universities and Colleges, FY 1975, tables B-7, B-48
Table 6	NSF, Federal Support to Universities, Colleges, and Selected Nonprofit Institutions, FY 1975, table B-9
Table 7	NSF, Federal Support to Universities, Colleges, and Selected Nonprofit Institutions, FY 1975, table B-9; and Raymond Woodrow, Federal Grants and Contracts to Colleges and Universities, pages 49-III to 51-III
Table 8	NSF, Federal Funds for Science, FY 1956, 1957, and 1958, table 12
Table 9	NSF, Funds for Scientific Activities in the Federal Government, FY 1953 and 1954, table 8, and NSF, Federal Support to Universities, Colleges, and Selected Nonprofit Institutions, FY 1975, tables B-2 and B-33
Table 10	NSF, Scientific R&D in Colleges and Universities, 1953-54, table 11; NSF, Scientific Activities at Universities and Colleges, 1964, table A-4; and NSF, Expenditures for Scientific Activities at Universities and Colleges FY 1975, table B-35
Table 11	NSF, National Patterns of R&D Resources 1953-1977, table B-1

Table 12	NSF, Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1975, 1976, and 1977, page 4; Vannevar Bush, Science, the Endless Frontier, page 86; and NSF, National Patterns of R & D Resources, 1953-1977, table B-1
Table 13	National Science Board, Science Indicators 1976, table 1-1
Table 14	National Science Board, Science Indicators 1976, table 5-24
Table 15	National Science Board, Science Indicators 1976, table 1-14